Charles University in Prague

Faculty of Social Sciences

Institute of Economic Studies

MASTER THESIS

Estimating the Euro effect with Synthetic Control Method for Eastern Europe

Author: **Bc. Martin Janota**

Supervisor: **Doc. PhDr. Petr Teplý, Ph.D.**

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Declaration of Authorship

The author hereby declares that he compiled this thesis independently, using only the listed resources and literature, and the thesis has not been used to obtain a different or the same degree.

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Prague, May 15, 2015

Signature

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Abstract

This thesis estimates the effect of Euro adoption on newest Eurozone members using synthetic control method. The effect is estimated on income per capita and GDP growth. Estimates indicate overall indecisive effect for Slovakia and Malta, neutral effect for Estonia and negative effect for Slovenia and Cyprus. The cost of Euro for Cyprus is estimated to be as high as 1/3 of GDP per capita. In some cases the direction of the effect changed before and after the financial crisis. The quality of inference suffers from low number of observations. Methodological assumptions are discussed, concluding that quality of Eastern European time series likely causes substantial bias in the results.

JEL Classification	C21, C23, F15, F43, N14
Keywords	euro, synthetic control method, income per capita, GDP growth, European Union, currency adoption
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Author's e-mail	mjanotacs@gmail.com
Supervisor's e-mail	teply@fsv.cuni.cz

Abstrakt

Tato práce odhaduje efekt zavedení Eura na nejnovější členy Eurozóny pomocí synthetic control metody. Efekt je odhadován na HDP per capita a na růstu HDP. Odhady ukazují celkově nerozhodný efekt pro Slovensko a Maltu, neutrální efekt pro Estonsko a negativní efekt pro Slovinsko a Kypr. Náklady zavedení Eura pro Kypr jsou odhadovány až do výše 1/3 HDP per capita. V některých případech se směr efektu změnil po finanční krizi. Rozhodnost závěrů je ovlivněna malým počtem pozorování. Práce diskutuje předpoklady použití metodologie se závěrem, že kvalita dat pravděpodobně výrazně zkresluje výsledky.

Klasifikace	C21, C23, F15, F43, N14
Klíčová slova	euro, synthetic control method, příjem per capita, růst HDP, Evropská Unie, přijetí měny
Rozsah	90 052 znaků

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Acronyms

ADH	Abadie, Diamond and Hainmmueller
DID	Difference in Differences
DSGE	Dynamic Stochastic General Equilibrium
EC	European Community
EFTA	European Free Trade Association
ERM	Exchange Rate Mechanism
EU	European Union
IMF	International Monetary Fund
PPP	Purchasing Power Parity
(R)MSPE	(Root) Mean Squared Prediction Error
SCM	Synthetic Control Method
SDR	Special Drawing Rights
WB	World Bank

Master Thesis Proposal

Institute of Economic Studies
Faculty of Social Sciences
Charles University in Prague

Author:	**Bc. Martin Janota**	Supervisor:	PhDr. Petr Teplý Ph.D.
E-mail:	mjanotacs@gmail.com	E-mail:	teply@fsv.cuni.cz
Phone:	+420736155935	Phone:	+420 222 112 326
Specialization:	*Economics and Finance*	Defense Planned:	June 2015

Proposed Topic:

Estimating the Euro effect with Synthetic Control Method for Eastern Europe

Motivation:

Estimating the effect of Euro adoption is a very lively topic in European economics. Most countries that have adopted Euro already have sufficiently long time series for evaluation and quantitative estimates of Euro effect are pouring in. The most common method of estimation is differences-in-differences (DID) approach. Recently, estimation of average treatment effect using synthetic counterfactuals, so called *synthetic control method,* became very popular thanks to its simplicity.
Synthetic control method (SCM) is supposed to systematically compare case studies and introduces quantitative inference in qualitative comparison. It has been introduced first in Abadie et al. (2003) to simulate effects of terrorism in Basque country. The method has since been applied to estimate: effect of anti-Tobacco program in California (Abadie et al. 2007), effects of inflation targeting (Lee 2011),effects of economic liberalization (Billmeier et. al 2012) capital controls in Brazil (Jinjarak et al., 2013), value of bank's political connections in crisis (Acemoglu 2013), costs of German reunification (Abadie et al. 2014). Lately, the method has been applied to estimate effects of joining EU or Eurozone (for example Campos et al. 2014 or Aytug 2014) and lot more applications in this area are to be expected.
The SCM is very simple, powerful and has many benefits over DID approach. It still rests on a number of assumptions though, that are often being violated.
In this thesis I want to discuss SCM and the Euro adoption effect estimation for countries with only short time series available: Slovakia, Balkan countries, Baltics, Malta and Cyprus; and estimate the effects for those countries.

Hypotheses:

1. Hypothesis #1: Significant change in GDP per capita can be attributed to Euro adoption for selected country.
2. Hypothesis #2: The effect was positive for selected country.
3. Hypothesis #3: During the crisis selected country performed better with Euro, than it would without it.

Methodology:

I am going to use *synthetic control method*, as implemented in Abadie et al. (2014). Synthetic control method is used to provide quantitative inference in small-sample comparative studies, as is the case with countries. The method constructs a synthetic counterfactual, which is then compared to development of the real variable over time. The difference between the two is then the effect of the event at some point in time.
Significant advantage of the method over panel regressions with dummy variables lies in accounting for unobserved time varying factors affecting the outcome. The synthetic variable is constructed so that unobserved factors should be the same as in the real variable, if requirements (specified in Abadie et al., 2007) on the dataset are satisfied. One of the main requirements is sufficiently long time series. In case of rather young countries of Eastern Europe with sometimes not even 20 years of observations this is a problem and needs to be

addressed during the estimation.
The computation itself is straightforward, the algorithm creates linear combination (weights) of countries which best corresponds to the country in focus. This is done on a pre-treatment period. After that we have a synthetic country which we can compare with the development of the real country. Two target variables will be considered GDP per capita, PPP and GDP growth rate. A range of growth predictors to estimate the country weights will be tested: measures of education, investment, trade openness, demography, inflation and productivity, labor market. The weights are estimated in such a way, that the root mean square error between the synthetically constructed variable and the real variable (GDP per capita/GDP growth) will be minimized. After the weights are estimated we can plot the real variable and the synthetic-weighted one, where the synthetic should reflect what would be the real variable if the event (Euro in our case) never happened. The difference is the treatment effect.
The data will be collected for publicly available IMF and WB databases.
The credibility of the result can be confirmed using “placebo test”, that is, rerunning the model for different in/out-of-sample observations to confirm that resulting difference between synthetic and real variable really is due to the event; or rerunning the model for countries in the control group to confirm that the observed effect is unique to the country in focus. Statistical significance of the difference between the real and synthetic variable can be assessed with confidence intervals randomly drawn from the control group, as shown in Acemoglu et al. (2013).

Expected Contribution:

I will discuss the data requirements and assumptions of SCM in context of Eastern European countries and short time series. The SCM assumptions and data quality in the region are hard to reconcile. I want to find a suitable compromise based on economic intuition as well as statistical approach.
Most of the current stream of synthetic matching and Euro effect estimation concentrates on Western Europe. I concentrate on Eastern Europe where many more countries are expected to adopt Euro, so the topic still has relevance for future policy. For the selected countries I will estimate the Euro effect on GDP per capita on the most recent data.

Outline:

1. Introduction: This section provides motivation for the thesis.
2. Literature review for Euro effect: Here I collect estimates of Euro adoption effect for comparison.
3. Methodology: In this section synthetic control methodology is discussed, the theory and applications. I will discuss the assumptions, interpretation of results and inference with placebo tests.
4. Data: This section will go through selected Eastern European countries, SCM and Euro case by case. Then the variables will be discussed.
5. Results: This section will cover the results from estimation. It will address country weights, variable fit and inference with placebo tests.
6. Conclusions: Finally section will sum up the results for each estimated country and discuss the implications for countries about to join Eurozone. Implications for using SCM on this imperfect dataset will also be discussed.

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Author **Supervisor**

1 Introduction

The common European currency has been a topic of academic and policy debate for a while now. Eurozone has grown from eleven members in 1999 to current nineteen. With the exception of Greece, all countries joining Eurozone later were those who joined EU during Eastern Enlargement in 2004. Countries still waiting to adopt Euro are from the same group. The discussion of costs and benefits of Euro adoption halted with the outbreak of financial crisis, followed by sovereign debt crisis. Euro adoption considerations of candidate countries were postponed at that time. Now the immediate concerns of financial crisis are over, Euro still stands and the question of whether the remaining EU countries should strive for Euro adoption is on the table again. Countries evaluating their Euro adoption stance now have the advantage of retrospective evaluation of Euro adoption effects. Such evaluation is typically approached within case study framework, comparing countries one-to-one, looking for differences between those who adopted Euro and those who did not. Verifying the effects with robust statistics is difficult due to small sample nature of the data. There are two reasons for this; first currency adoption in Europe is naturally not a commonly observed phenomenon; second the (mostly Eastern European) countries in focus have reliable time series starting only in 1990s. An attempt to overcome the small sample issues and introduce some quantitative inference into case studies, would be to employ methods with synthetic counterfactuals. These methods rely on construction of synthetic unit which mimics the real observed series up to certain intervention date, the difference between real and synthetic series after then is the estimated effect of the intervention. The approach is well suited for the task, since it has less strict requirements on the sample size.

This thesis attempts to estimate the effects of Euro adoption on income per capita at purchasing power parity and growth rates using synthetic controls for Southern and Eastern European Euro adopters. An important part is discussion of the data requirements and applicability of synthetic control methodology, since the short series make deriving credible inference from the method a challenge.

The rest of the thesis is organized as follows: Section 2 provides context to the estimation task. Section 3 reviews literature relevant for estimating currency adoption effects and synthetic control method. Section 4 provides overview of the synthetic control methodology, discusses its theoretical issues and implications for the application. Section 5 is a description of data availability and modelling dataset selection. Section 6 provides estimation results per country and discussion of the results. Section 7 concludes. Appendices hold tables and figures which are referenced to in the text, but for the sake of clarity and consistency of the text are appended at the end.

2 Background: Euro and new EU members

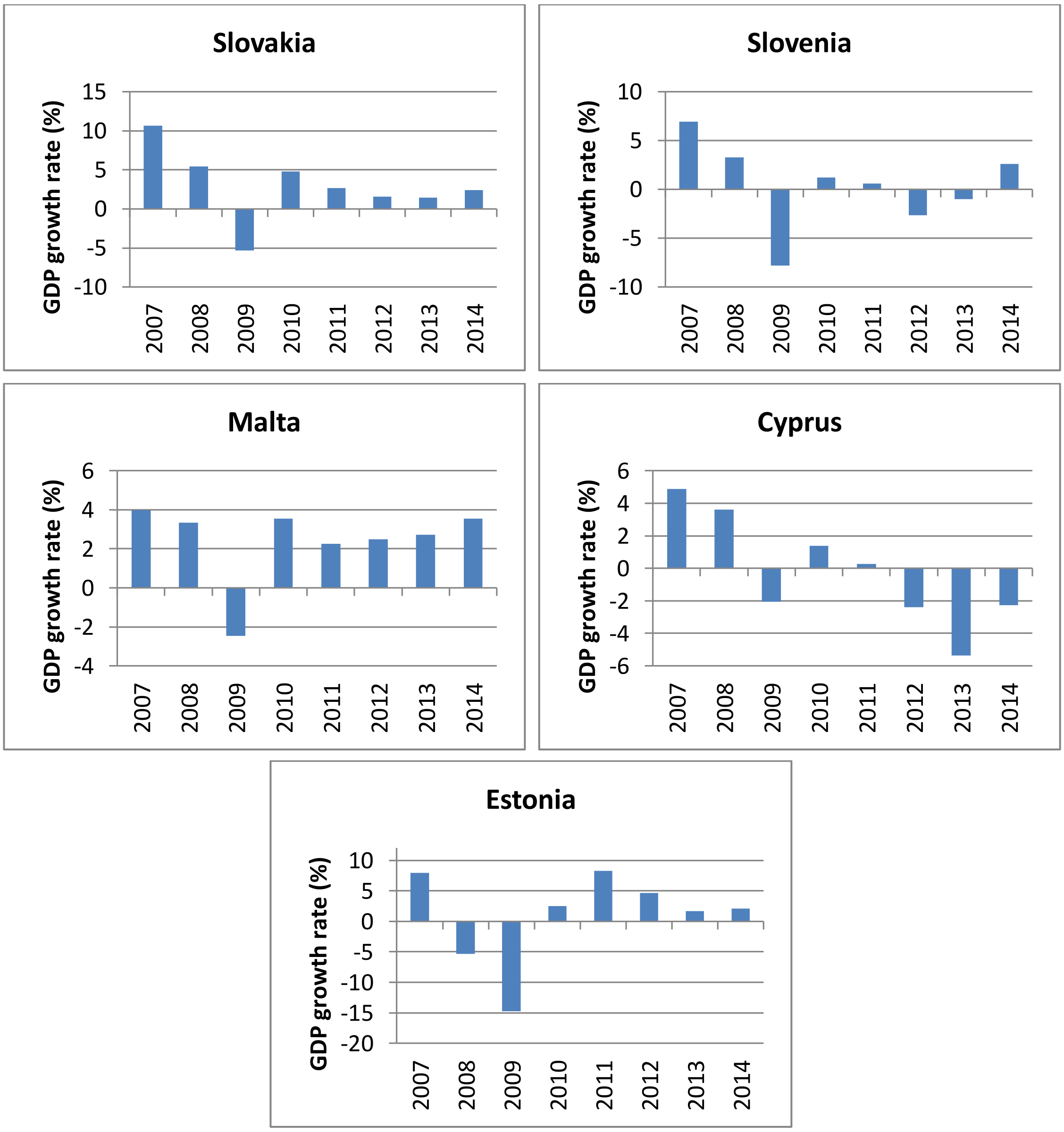
Unlike EU members in 1999, later entrants vowed to adopt Euro at some future date. Of the thirteen countries who joined EU in 2000s, seven already adopted Euro. Table 1 provides overview of all relevant European countries and their relationship towards EU and Euro.

Table 1: European countries and the Euro

Country	Joined EU	Joined ERM II	Adopted Euro	note
Albania				
Austria	1995		1999	Euro as only currency since 2002
Belgium	1957		1999	Euro as only currency since 2002
Bosnia and Herzegovina			pegged since 1999	peg to German Mark, later to Euro
Bulgaria	2004		pegged since 1999	peg to German Mark, later to Euro
Croatia	2013			policy of keeping exchange rate vis-a-vis Euro stable until January 2015
Cyprus	2004		2008	
Czech Republic	2004			
Denmark	1973	1999	narrow ERM II since 1999	
Estonia	2004	2004	pegged since 1992/1999, adopted 2011	peg to German Mark, later to Euro
Finland	1995		1999	Euro as only currency since 2002
France	1957		1999	Euro as only currency since 2002
Germany	1957		1999	Euro as only currency since 2002
Greece	1981	1999	2001	
Hungary	2004			
Iceland				
Ireland	1973		1999	Euro as only currency since 2002
Italy	1957		1999	Euro as only currency since 2002
Kosovo			2002 (unilaterally)	peg to German Mark, later to Euro
Latvia	2004		pegged since 2005, adopted 2014	peg to SDR, later to Euro
Lithuania	2004	2004	pegged since 2002, adopted 2015	peg to US dollar, later to Euro
Luxemburg	1957		1999	Euro as only currency since 2002
Macedonia				
Malta	2004	2005	2008	
Montenegro			2002 (unilaterally)	peg to German Mark, later to Euro
Netherlands	1957		1999	
Norway				
Poland	2004			
Portugal	1986		1999	Euro as only currency since 2002
Romania	2004			
Serbia				
Slovakia	2004	2005	2009	
Slovenia	2004	2004	2007	
Spain	1986		1999	Euro as only currency since 2002
Sweden	1995			
Switzerland				
Turkey				
United Kingdom	1973			

This thesis focuses the newer Eurozone members, mostly from Eastern Europe. Lithuania and Latvia joined the Eurozone very recently are there is not much to evaluate yet. Countries which already have a few years of observations after Euro adoption are Slovakia, Slovenia, Estonia, Malta and Cyprus. Each of those countries adopted Euro in different macroeconomic context and each country fared differently through the financial crisis and sovereign debt crisis later.

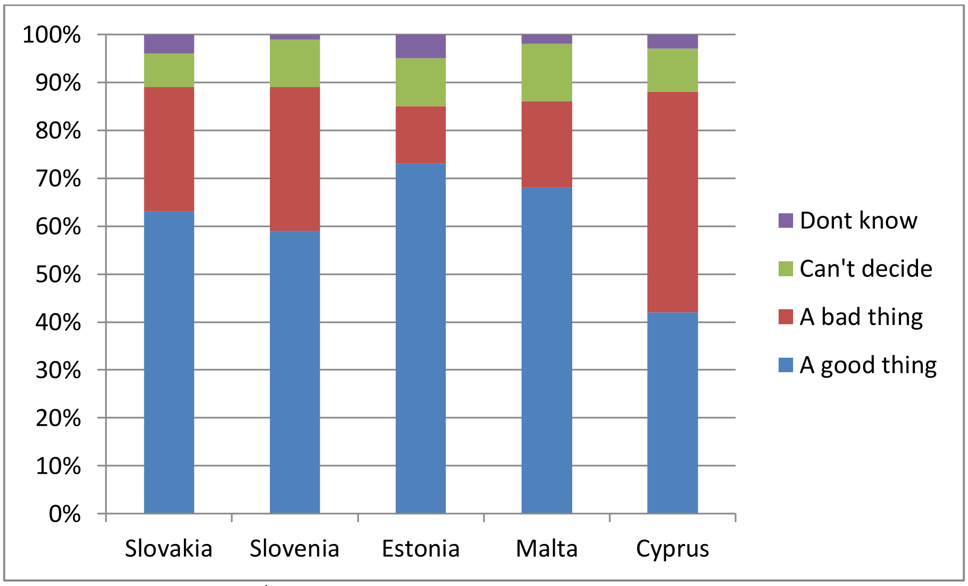
Figure 1: Country growth rates



Source: World Bank Database

Slovakia adopted Euro in the wake of the crisis. Opinions as to whether it was a relief or burden differ. Slovak sources (Figure 2) tend to be more positive, while foreign sources (see next section) are more skeptical. Slovenia's Euro adoption was smooth with no controversies before or immediately after the adoption. Nonetheless in the following years, the country experienced prolonged recession (Figure 1) coupled with weakness in the (state involved) banking sector. Whether Euro is to blame is an open question towards which this thesis is trying to contribute. Estonian currency has been historically pegged to Euro and thus Euro adoption did affect the economy through exchange rate channel, but rather had effects relating to being member of a larger policy area. The adoption of Euro in the Baltic countries was delayed due to financial crisis and by the time Estonia got to introduce the common currency, it had already gone through severe recession (Figure 1) and real adjustment. Maltese growth remained stable throughout the observed period. The case of Cypriot Euro adoption coincided not only with financial crisis but also with substantial shift in government, Greek sovereign debt crisis and connected banking crisis. These effects are difficult to separate.

Figure 2: Public poll asking "Having the Euro is a good or bad thing for your country?"



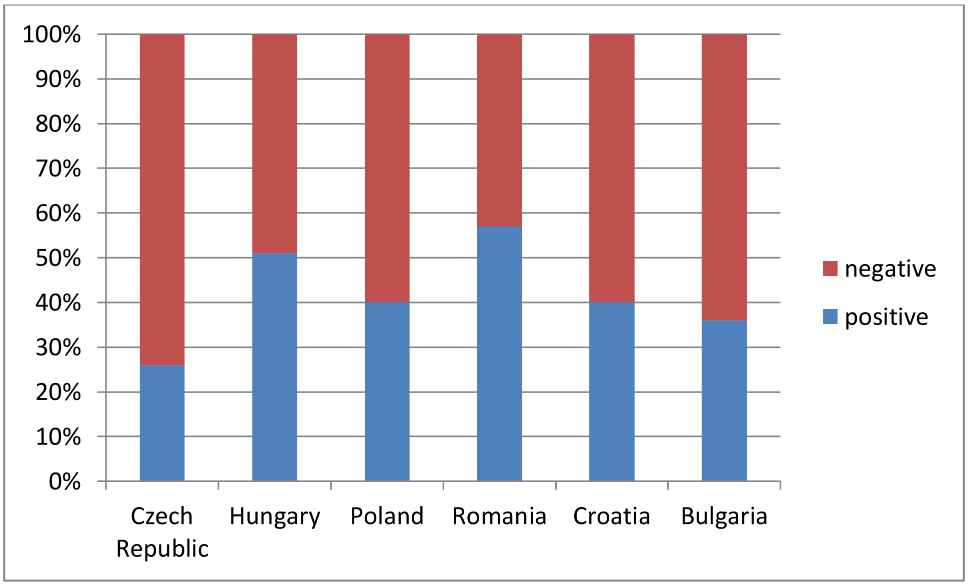
Source: Eurobarometer[1], October 2014
Note: Categories correspond to legend top-to-bottom

There are two groups of prospective Eurozone members, the countries with currencies already pegged to Euro to some extent and countries which so far follow independent monetary policies. In the first group is Bulgaria and Croatia. In the second there is the Czech Republic, Poland, Hungary and Romania. Bulgarian currency has been pegged to Euro since its introduction in 1999. Now the country satisfies all convergence criteria except for two year ERM II membership. It could potentially enter

[1] Available at: http://ec.europa.eu/public_opinion/topics/euro_en.htm

the Eurozone as early as 2018. Croatian kuna has also been linked to Euro though not pegged at fixed rate. In January 2015 the country decided to follow Swiss Franc instead, due to large share of foreign denominated debt in the country. Croatia does not satisfy three of the convergence criteria (budget deficit, debt to GDP and ERM II membership. It is unclear when it might be able to join Eurozone. Although Czech Republic and Poland are able to fulfill the convergence criteria in a few years, there is little political will and strong public opposition against Euro adoption at the moment (Figure 3). Hungary is struggling with its government debt levels and is unlikely so satisfy the convergence criteria anytime soon. Romania may satisfy the nominal Maastricht criteria in the coming years, however it still lags in terms of real convergence.

Figure 3: Public opinion on the consequences of introduction of the euro in the respondent country



Source: Eurobarometer, April 2014
Note: Categories correspond to legend top-to-bottom

3 Literature Review

In this section the *Euro effect* is understood as direct economic implications of Euro adoption, may those be trade or welfare related. Most research so far relates to trade effects of Euro adoption, this thesis is concerned with welfare and growth effects of Euro adoption. The literature review section starts with general overview of currency union literature and literature on trade effects first, since these are most researched. Following sections review relevant literature on welfare and growth effects of Euro, applications of synthetic control methodology, estimates of effect of formation of EU itself and finally estimates of Euro related effects for the target countries.

3.1 Monetary unions and trade effects

The main theoretical reason for a common currency among European Union (EU) countries is the effect on the intra EU trade. This rests upon the idea of optimum currency area formulated in Mundell (1961), McKinnon (1963) and Kenen (1969). However, the EU never fulfilled the listed criteria. Although the currency union may become optimum currency area endogenously - Frankel and Rose (1997 and 1998); there is also theory explaining why countries may diverge - Krugman (1993); and evidence indicates that indeed in some cases divergence is more likely Caporale et al. (2013). Thus the theoretical effects of the engineered common currency were unclear.

There is consensus regarding the general costs and benefits of currency integration. Stable exchange rate environment and credible monetary policy facilitate low interest rates, increase in trade, competition and productivity and also income per capita growth. The long term costs relate to losing adjustment tool in the form of exchange rate, independent monetary policy stance and transmission of negative shocks throughout the monetary union. Despite agreement on the theoretical factors that affect costs and benefits of integration, there was less clear consensus on the practical effects of Euro introduction. While the discussion about costs and benefits was theoretical ex-ante Euro adoption, as soon as there were some observed effects, the Euro effects could be empirically estimated. First often cited empirical work on currency unions came from Rose (2000)[2], with staggeringly high estimated increase in trade flows among the currency union members. Barro and Tenreyro (2003) supported these results with estimation based on instrumental variables. Among the first attempts at the trade effects of European currency was one made by Micco et al. (2003), where the size of the effect was already in single digits. A comprehensive review of literature by Baldwin (2006)

[2]Many later papers on the topic were co-authored by Rose, such as Rose (2001), Rose (2002).

also concludes that Euro effects cannot reach the magnitude estimated in the early literature. Most of the literature applied difference-in-differences (DID) estimation. This makes for a volume of comparable quantitative estimates of trade flow change in response to Euro adoption, which can be grasped meta-analytically. Havranek (2009) provides a quantitative overview of empirical literature at the time, concluding that most literature was marred with publication bias and - when accounted for these bias - the Euro effect was insignificant.

3.2 Welfare effects of the Euro

So far we discussed only the effect of Euro on trade flows. This effect can be modelled with gravity equations relatively with ease. Estimating the impact on growth and welfare is a path less travelled, though more interesting for the general audience. Frankel and Rose (2002) go in this direction, as they looked on income and not only trade with respect to currency adoption. There are estimates of what would the effect on welfare in Sweden, Denmark and UK be, had they adopted the common currency. Their per capita income was estimated to be 20% higher with Euro in this „Rosean“ stream of research. Carre and Collard (2003) use DSGE framework, finding benefits for households from positive technology and fiscal shocks under monetary union, compared to flexible exchange rates. Deverreux et al. (2003) use model based on sticky prices and conclude that common currency insulates countries from exchange rate volatility with positive welfare effects.

One problem with estimating the “what-if” welfare scenarios is that growth (or GDP level) is subject to shocks that are not easily identified and modelled. One possible solution is the use of synthetic counterfactuals which already control for unobserved factors to some extent. The problem then shifts from controlling for all relevant factors to constructing good counterfactual. An elegant method of modelling counterfactuals is the Synthetic Control Method (SCM).

3.3 Literature using Synthetic Control Method

The Synthetic Control Method is an econometric technique, designed for constructing synthetic counterfactuals for small samples. It works best when there is one single event in time that significantly affects only the treated unit and not the control units. The Synthetic Control Method was first used by Abadie and Gardeazabal (2003) to estimate the costs of terrorism in Basque country. Abadie, Diamond and Hainmmueller (2010, ADH from now on) estimated the impact California anti-tobacco program on tobacco consumption. Other applications were for example on the effects of: natural disaster on growth (Cavallo et al. 2010), inflation targeting (Lee 2011), economic liberalization (Billmeier et. al 2012), capital controls in Brazil (Jinjarak et al., 2013), value of bank's political connections in crisis (Acemoglu 2013), costs of German reunification (Abadie et al. 2014). The Synthetic Control Method is generally attractive for events that are observed very rarely and are specific to some well defined units (usually countries). In those cases traditional statistical inference techniques fall short, while SCM can deliver some quantitative estimates. Moreover, the simplicity makes estimation with SCM very easy to execute.

Recently, applications of the SCM extended to the Euro effect. Aytug (2014) estimated average treatment effect of adopting the Euro on GDP growth for all Eurozone countries. His results are mixed, the costs/benefits differ among countries and between periods. In some countries the effect was opposite before and after the crisis. Overall the impact of Euro on growth was found negative. A new contribution by Gomis-Porqueras and Puzzello (2015) is an application of SCM on Euro adoption. Authors estimated effect of Euro on income per capita for Belgium, France, Germany, Italy, Netherlands and Ireland. While the first four mentioned are estimated to have been better off without Euro, Irish income per capital would have been considerably lower. The effect on the Netherlands was estimated to be negligible.

3.4 EU vs Euro effect

An important distinction is between the effect of Euro and the EU itself. European economic integration is surprisingly a lot less empirically explored topic than trade effects of Euro adoption or trade liberalization in general[3]. What may be modelled as Euro effect may be in fact delayed effect of EU accession. This is particularly relevant for countries that joined the EU in 2004 and introduced Euro a few years later. Campos et al. (2014) estimated the effects of EU membership on GDP per capita and labour productivity for all EU members using SCM. They found strong evidence in favor of the integration. More specifically, Denmark, Ireland, UK, Portugal, Spain, Austria, Estonia, Hungary, Latvia, Slovenia and Lithuania are supposed to be strong beneficiaries; Finland, Sweden, Poland, Czech Republic and Slovakia are the mild beneficiaries; the only loser from EU membership in terms of GDP per capita and labor productivity being Greece. As for other estimates of the benefits of EU membership: Henrekson et al. (1997) found that EC and EFTA memberships do in fact have a positive and significant effect on economic growth, and that there is no significant

[3] See for example Baldwin(1989) or Baldwin and Seghezza (1996) for trade liberalization in Europe.

difference between EC and EFTA membership. According to Badinger (2005), EU GDP per capita would be lower by about 20% had there been no integration since 1950s.[4]

3.5 Estimates of Euro adoption effects in selected countries

This thesis estimates the welfare and growth effects of Euro for countries which adopted Euro later, but already have some number of observations after Euro adoption. Now, years after those countries adopted the common currency, there is still dearth of any ex post evaluation. A good source on estimates related to Euro and new Eurozone members are the central banks of the respective countries.[5] National Bank of Poland staff investigated the trade effects of the euro adoption primarily for Slovakia, Slovenia secondarily for Malta and Cyprus in Cieslik et al. (2012). They used a gravity equation enriched by incomplete specialization assumption, which reflects the lower share of intra-industry trade of the Central European countries. Their results show that Eurozone accession did not stimulate bilateral exports, even depressed them in the case of Malta and Cyprus. Moreover, even the parameter for ERM-II is not found significant. These results contrast with the ex-ante estimates, like Fidrmuc et al. (2006) or Frankel (2008), which generally predicted positive effects of Euro adoption. Another Polish work, Brzoza-Brzezina et al. (2012) provides literature review of effect of Euro on various macroeconomic indicators, concluding that existing studies report no substantial effects of the euro. They then simulate a scenario of hypothetical Polish euro adoption in 2007. Under such scenario, Poland would have experienced substantial increase in volatility. Similar conclusions are reached in Torój et al. (2012), who perform a counterfactual exercise on Poland and Slovakia. They estimate that Polish tradable output would be by 10-15% lower in 2009 with euro, while Slovak would be 20% higher without it.

Aristovnik and Meze (2009) studied the ex post effect of the Eurozone creation for Slovenian trade. They argued that the trade benefits of the entry of new countries into the Eurozone would not be the same as the benefits of the initial formation of the Eurozone in the nineties. Their analysis showed that there had been a positive effect on Slovenia's exports into and a negative effect on its imports from the Eurozone at the time of the creation of the Eurozone in 1999. However, they did not study the effects of 2006 Slovenia accession to the Eurozone ex post.

[4] Badinger (2010) is a good introductory source on estimation of effects of post war European economic integration.
[5] Keeping in mind, however, that there is potential scope for bias against euro in those institutions.

4 Synthetic Control Methodology

This section reviews synthetic control method in general. It starts with motivation why and when to use SCM. Then the Synthetic Control Estimator is established, followed by discussion of data related assumptions behind SCM and bias stemming from violating those assumptions. Section concludes with discussion of inference techniques in applied synthetic control work.

4.1 Motivation

First use of the Synthetic Control Method is attributed to Abadie and Gardeazabal (2003), two later contributions co-authored by Abadie expanded and formalized the technique – ADH (2010) and Abadie et al. (2014). The motivation behind developing this methodology was to have some “qualitative inference with quantitative bones” - Tarrow (1995), that is, having comparable case studies, with precise methodology and some quantitative results. The question which should be answered by this methodology is: “What would be the development of target variable in time, if one single important event did not occur in past.” This has been traditionally the domain of difference-in-differences estimation. However, as we discuss in this section, there are cases where DID is not as suitable as SCM. The SCM approach to modelling “what-if” scenarios is through constructing a synthetic counterfactual, which is then simply compared to the observed series. The counterfactual is constructed as weighted average of units in the control sample. Those units should be structurally similar to the treated unit (borrowing the term from medical studies), with the only difference being some event (intervention) at a single point in time (such as terrorist attack, natural disaster or adoption of Euro). Choosing a set of proper control units is essential, as it is the only stage of estimation, where one can account for possible bias. From there on, the SCM is nothing more than clear algorithm how the weights of control units are calculated to get a synthetic match. Nonetheless, as Abadie et al. (2014) put it:

“Formalizing the way comparison units are chosen not only represents a way of systematizing comparative case studies ..., but it also has direct implications for inference.” and *“... the main barrier to quantitative inference in comparative studies comes not from the small-sample nature of the data, but from the absence of an explicit mechanism that determines how comparison units are selected. By carefully specifying how units are selected for the comparison group, the synthetic control method opens the door to the possibility of precise quantitative inference in comparative case studies, without precluding qualitative approaches to the same data set.”*

The most pronounced advantage of synthetic control methods over regression based estimators is controlling for unobserved shocks affecting both control and treated units. The units in the (well chosen) control set should be theoretically affected by similar shocks as the treated unit. SCM weights in information which come after the intervention, regression techniques stop at the intervention date. SCM also does not require multiple observations of the intervention event, like regression techniques do.

The biggest strength and weakness of the method is that it was created as empirical – to solve specific task of modelling counterfactuals. The formalism was subdued at first. The ADH (2010) paper set SCM on more solid footing formally. There are still assumptions (mostly data quality related) behind it that are not well described in most applications and application of the method requires ex ante analysis of those assumptions (which is not always the case in some papers).

4.2 The Synthetic Control Estimator

There are plenty of excellent formal summaries of synthetic control method, some with more formal style, such as ADH (2010) some less technical, such as Abadie (2013). The underlying formalism remains the same. Therefore we only provide brief formal overview of the method. An interested reader will find more information in the aforementioned papers and other SCM literature in the References section or in Annex to this thesis.

Brief formal setup of synthetic control estimation goes as follows: Suppose we have J units, the first unit ($j=1$) being the treated one, i.e. the one which will experience intervention. The remaining $J-1$ units are the control group, unaffected by the intervention. Assume we have a total of T periods, split into T_0 pre-intervention periods and $T- T_0$ post-intervention periods. Now for each unit j and time t we observe outcome variable Y_{jt}. For each unit j we also have observed vector of unit characteristics (X_{1j},…, X_{kj}). We define Y_{it}^N as the outcome variable in case of no intervention. Then, for the affected unit $j=1$, with post-intervention periods $t \in [T_0 + 1, T]$, we are interested in the treatment effect in periods after intervention:

$$\alpha_{1t} = Y_{1t} - Y_{1t}^N \tag{1}$$

For the whole sample period the aggregate treatment effect is equal to:

$$\sum_{t=T_0+1}^{T} \alpha_{1t}$$

Now the problem is how do we get Y_{1t}^{N}, the outcome variable in the absence of intervention, the counterfactual outcome. We do this by creating synthetic equivalent of treated unit $j=1$, using the units $j=2,\dots,J$ in the control group. Each control unit will be assigned weight w_j, so that the synthetic control estimator is a weighted combination of the control units:

$$\hat{Y}_{1t}^{N} = w_2 Y_{2t} + \cdots + w_J Y_{Jt}$$

And the estimator of treatment effect is:

$$\hat{\alpha}_{1t} = Y_{1t} - \hat{Y}_{1t}^{N} \tag{2}$$

A feature of SCM is non-negative restriction of unit weights: $w_j \in [0,1]$, to avoid extrapolation; and of course weights have to sum to one:

$$\sum_{j=2}^{J} w_j = 1$$

The restriction to non-negative weights can be relaxed, but the interpretability of the modelled counterfactual is one the advantages of SCM.

What remains to solve is the procedure of obtaining the optimal weights. In ADH (2010) it is proposed to use the unit characteristics ($X_{1j},\dots, X_{1k}$) to calibrate the weights. We will be looking for a vector of weights w^{*}, that will minimize the following metric:

$$\sum_{i=1}^{k} v_i \left(X_{i1} - \sum_{j=2}^{J} w_j \, X_{1j} \right)^2 \tag{3}$$

The weights $v_1,\dots, v_k$ reflect the relative importance of the synthetic control reproducing the values of the characteristics ($X_{1j},\dots, X_{1k}$). Metric (3) can be minimized with given set of weights $v_1, \ldots, v_k$. This is straightforward quadratic optimization problem. Now the question is how to choose the right combination of weights $v_1, \ldots, v_k$. These weights represent the importance we place on variables that characterize each unit. Until now the estimation procedure has been rather simple, with not many possible deviations. Here may be a point of divergence where papers get different results based on how they approach this weight selection problem.

In Abadie (2013) four approaches are described:

1. Subjective setting of weights $v_1, \ldots, v_k$. Researcher may have reasons for a specific vector of weights.
2. Running a regression of the form: $Y_t = \alpha + X_t\beta + \varepsilon_t$, where relative predictive power of components $\beta_1, \ldots, \beta_k$ of vector β will be used as weights.
3. Choosing weights $v_1, \ldots, v_k$ that produce the best fit in term how synthetic control tracks treated unit, measured by outcome variable during the pre-intervention period. The task will be to minimize the pre-intervention prediction error: $Y_{1t} - \hat{Y}_{1t}^N$, over the whole period (i.e. MSPE). This adds a layer of computational complexity. (There is an option to enable this nested optimization in the *Synth*[6] package – probably the most widely used script for SCM. This thesis uses this approach.)
4. The last method assumes long pre-interventions time series, which can be split into training and testing samples. The weights would be estimated on the training sample the same way as in previous point. The mean square prediction error would then be validated on the testing sample. This process will iterate until MSPE on the testing sample is small enough. Then we take resulting weights $v_1, \ldots, v_k$ from the testing period and use it to calculate the final unit weights w^*. (This approach is not used in this thesis, due to short time series.)

Those were estimation setup related issues. Beyond that, differences in estimation results may stem from different optimization algorithms used by statistical packages. This is beyond the scope of this thesis. Interested reader will find more information on the optimization algorithms in Abadie, Diamond and Hainmueller (2011), a paper dedicated to the *Synth* package, and in references contained therein.

[6] Available from Hainmueller's webpage: http://web.stanford.edu/~jhain/synthpage.html

4.3 Assumptions

This section collects assumptions listed in works applying synthetic control methodology. Although one declared advantage of SCM over DID is that SCM is identified under weaker assumptions, there are still conditions that should hold for SCM to be proper tool. An excellent starting point for discussing SCM assumptions would be short methodological paper by Abadie. Abadie (2013) lists six assumptions[7]:

1. Size of the intervention effect and volatility of the outcome
    - The estimated intervention effect has to be large enough not to be confused with other interventions
    - The effect should also still be sizeable given the volatility of the series on which it is measured
2. Availability of a comparison group
    - There have to be enough units not affected by similar intervention[8]
    - Units affected by extreme, unique shocks should be excluded[9]
    - Control units should have similar characteristics as the treated unit (measured by the predictor variables used in matching)
3. No anticipation
    - Intervention date should be set in estimation to account for it being anticipated by forward looking agents (currency adoptions are usually well anticipated)
    - It may be useful to pre-date the intervention date in estimation to the moment when it was decided, rather than implemented
4. No interference
    - Control units significantly indirectly affected by intervention in treated unit should be excluded (no spill-over effects)
5. Convex hull condition
    - The treated unit characteristics have to fall in convex set of characteristics of the control units, see Figure 4

[7] Most of these are not unique to SCM, but also apply to DID or case study research design.
[8] Obviously in case of Euro adoption, this restricts the control units to countries that did not adopt Euro, and are not even closely pegged to the currency, such as Denmark or Bulgaria.
[9] Greece is an example of outlier as a country.

6. Time horizon

   - Effects of intervention may need time to fully demonstrate
   - Therefore they should be observed on sufficiently long period

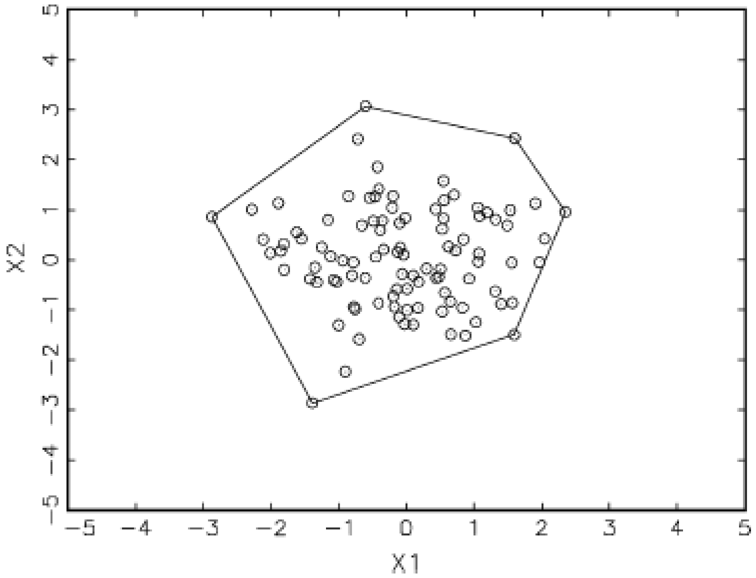


Figure 4 : Interpolation vs. extrapolation: The convex hull of X is the smallest convex set that contains the data. Inference on points inside the convex hull requires interpolation; inference outside it requires extrapolation. Source: King (2006)

Violation of these assumptions does not always mean the method is infeasible for a given task:

1. The first assumption is about the proper choice of outcome variable and intervention. The outcome variable should be something where treatment effect can demonstrate and the effect has to something distinct and irregular. If there is too much noise in the series, some of it may be filtered out to make the intervention effect more pronounced.
2. The second assumption is most tricky one, as control sample heavily impacts the final results. It is not quite clear when the assumption satisfied. Both intuition and quantitative analysis should be employed during selection of control units. There will always a subjective input of the researcher. Using more quantitative approach may diminish the subjective bias, but sometimes at the cost of interpretability of weights and synthetic estimates.

3. Missing the beginning of the intervention effect diminishes the magnitude of the effect. If the synthetic was estimated on low number of observations (short series), then is also messes up the synthetic. So this assumption is more of a concern when there are only short time series available.
4. Violating assumption 4 may be source of bias in the same direction as the treatment effect. Thus it exacerbates result, as opposed to violating Assumption 3, hence these two may cancel out. The "no inference" assumption contradicts the idea that controls should be similar to treated unit. In case of countries, the control countries will often be regionally clustered and will experience spillover effects. This bias can be mitigated by excluding large countries with significant spillover effect from the sample.
5. Violation of assumption 5 is still manageable as long as the outlier variable is not the outcome variable. If the treated unit's outcome variable lies outside the convex hull of controls, it cannot be approximated by interpolation. An easy remedy would be differentiation. For example a country whose GDP level cannot be approximated can be modelled based on GDP growth rates.
6. Assumption 6 is there to make the conclusions we make about the treatment effect comprehensive and definite. It is more of an issue if the onset of the treatment effect is expected to be gradual. However its violation does not invalidate a partial result, though the "partial" status should be mentioned.

4.4 Bias

The synthetic control estimator is *asymptotically* unbiased in the sense that bias decrease with increasing number of pre-intervention observations. The formal proof is in Appendix B of ADH (2010). A practical implication is that short pre-intervention period makes the results biased; the more the shorter the series; when choosing data sources, the available series length should be the first concern.

A common type of bias which may occur when using SCM is the *interpolation bias*. This type of bias arises when control units with too different characteristics are employed.[10] Although there may exist a linear combination of controls that matches the treated unit quantitatively well, it has no real world counterpart. Unfortunately this bias is commonly ignored in SCM applications. Data often does not provide sufficiently homogenous control group. The brute solution is to relax the requirements on similarity of control units to the treated one, use whatever matches well and accept the interpolation bias. See ADH (2010) p.495, for formalization of interpolation bias in SCM. An excellent overview of extreme counterfactual related issues is in King (2006). The interpolation bias is most severe regarding the outcome variable, nonetheless it may happen that a unit (say country) has some characteristic (say inflation) which is extreme compared to all units in control group. Such was the case in Abadie et al. (2014), where German price stability could not be matched by any country in the control sample. Authors argued that as long as the overall match is good, this minor issue can be ignored. However, as long as the only criterion is how closely the synthetic matches the observed in pre-intervention period, then it can always be arranged so that the resulting plots will look very intriguing, however the results will not be comparable across studies. If there is to be some use to the results in research, they have to be comparable and the more detailed is the description of the procedure leading to those results, the more credibility they have. Therefore the SCM is applied very conservatively in this thesis, with no aim to find a powerful synthetic match at all costs. Rather the goal is to discuss when the application to our task (estimation of Euro effect for Eastern European countries) is not smooth.

So far many papers employing synthetic control methodology omit to present fulfillment status of all the mentioned assumptions or steps leading to the results: sample selection, data quality – missing observations and length of time series, discussion of interpolation bias, variable tests for hull convexity, optimization procedure used to acquire country weights, reporting country weights, running placebo tests for both the timing and the magnitude of the treatment effect. This illustrates that the methodology is not quite settled yet.

4.5 Inference

Perhaps the most challenging as aspect of Synthetic Control Method is confirming credibility of the results. Given the nature of most SCM applications – small

[10] For example if we would construct synthetic Germany with weights including Somalia on one end and Seychelles on the other, it is hard to reason why should Germany bear any similarities to those countries, let alone, lie “between” the two. Abadie et al. (2014) restricted their sample to OECD countries when making synthetic Germany to reduce this kind of bias.

samples, only one (or few) units affected by intervention – the standard inference techniques with standard deviations and confidence intervals are inapplicable here.

There are two types of widely used tests, test that should help identify spurious results and falsification tests, which check underlying assumptions. The former group is represented by placebo tests. First application of placebo test is to confirm that the intervention date is unique. To conduct this test we can compute the synthetic control using simulated different intervention date. Then we observe if there is still noticeable deviation between out-of-sample synthetic match and real series after the real intervention date. If not, then the intervention date was truly special. This test is utilized in almost all SCM applications including ADH (2010) and Abadie et al. (2014). It is also employed by Campos et al. (2014) to look for anticipation effects, by predating EU-accession during the 2004 enlargement to 1998.

Another simple measure that helps check good fit as well as intervention date and treatment effect magnitude is the ratio of post-intervention RMSPE to pre-intervention RMSPE. Should the intervention effects be sizeable, the post-intervention RMSPE will be relatively large. If the synthetic matches well in the pre-intervention period, then pre-intervention RMSPE will be relatively small. Resulting ratio thus captures both quality of matching and magnitude of effect. Misplacing the split between, pre-intervention and post-intervention periods will also affect the ratio. Hence it is very intuitive scale-free metric which captures most important features of SCM.

Second type of placebo tests, commonly deployed for SCM validation, is running the same estimation setting (same controls, same intervention date) for each of the control units. If the path produced by the synthetic unit in focus is unlikely to be reproduced by any control, then we can deem it significant. From the volume of placebos, pseudo p-values can be calculated. Intuitively it is the probability that given magnitude of treatment effect will be observed, measured by how many placebos reproduce the same magnitude treatment effect, more formal drawing of p-values is described in Cavallo et al. (2010). The thesis shows a formal way to calculate p-values of the treatment effect per period from the placebo results. This type of placebo tests implicitly assumes that the estimators follow the same distribution and are uncorrelated. In Abadie et al. (2014) this test is mentioned but not employed. It would have been interesting to see the test results, given that there likely was a correlation with the control group, as unification of Germany had spill-over effect on its neighbors.

In general, even placebo tests rely on some large sample properties, which are absent in many small sample SCM applications. In synthetic control applications, the control sample is constructed conditional on the treated unit and may not be suitable for estimating one of the controls. ADH (2010) exclude units with pre-intervention MSPEs more than five times higher than the treated unit MSPE. Placebo studies for these units do not provide information to measure the relative rarity of the post-treatment gap obtained for the treated unit which was well-fitted prior to treatment (Abadie et al., 2011). In such cases the aforementioned tests are not as good gauge for validity of the result. Hence it remains a question, how reliable can they be in each particular case.

Second type of tests, falsification tests, aim at checking whether the intervention only had effect on the treated unit and not on controls. This is practically done using so called leave-one-out tests. That is, removing units from the control set one-by-one. If the unit weights change severely, in response to different composition of the control set, then their robustness is to be questioned. It means that the sample is either too small or that the synthetic depends excessively on one control unit. Same applies to the predictor variables, if slightly different set of variables yields very different resulting unit weights, then the quality of matching is a concern. These checks may also serve as an empirical guide when number of observations is too small. When this happens, the unit weights will become unstable and will swing excessively with changes in control sample.

An elegant approach to inference with SCM is applied in Acemoglu et al. (2013). Their application of SCM gives them many treated units, which enables them to construct confidence intervals. They do so by bootstrapping 1000 random placebo treatment groups, each group the same size as the real treatment group, computing the treatment effect for each of those groups and constructing confidence intervals. Although, one should be aware that large sample properties upon which p-values depend, are absent in many case study applications. Some academic work, such as Acemoglu et al. (2013), Aytug (2014) or Campos et al. (2014), use multiple estimation techniques and the lack of statistical significance in SCM is compensated for with statistical significance in other (usually DID) approaches. Then SCM serves to get point estimates, while DID to establish significance. A very interesting approach is one opted for in Gomis-Porqueras and Puzzello (2015). They first run SCM to get estimates of the treatment effect, which is in turn used as an outcome variable in DID approach. This approach has great added value in relating the treatment effect components to specific economic factors and it also helps validate the significance of SCM results.

This thesis employs mentioned weight robustness checks and RMSPE check for intervention date effects. Placebo tests with control group to derive pseudo p-values were not feasible, due to poor matching of most countries in the control samples. Inference for synthetic control methods is an inventive area of research as every other paper introduces a modification to the currently used tests or introduces a new one.

5 Data and Sample selection

There is not much dispute over the synthetic control estimation procedure. It is simple and straightforward. The computational aspects of SCM applications do not change much. What differs across literature is data selection. Unfortunately, the choice of data may have more profound impact on the results than differences in methodology. In literature in many cases the section on data selection is very brief and it is impossible the reconstruct the same results just based on this information, as there was substantial unmentioned input by the researcher during data handling. This thesis attempts to follow a clear and detailed procedure of obtaining the control group and set of variables. This section discusses factors that played role in dataset composition.

5.1 Length of period

For the task outlined – estimation of treatment effect of Euro for selected 2004 EU entrants – there are rather short series available. This is due to historical reasons. First off, many eastern European countries did not even exist in their current borders (Czech Republic, Slovakia, Baltic States, successors of Yugoslavia) 25 years ago. Second even the countries that have not changed in borders have the desired time series (such as national accounts) available in good quality only after 1990. This limits the maximal length of time series we can get to 1990-2013. This leaves us with about 16 to 20 yearly pre-intervention observations and 3 to 7 post-intervention observations, depending on country. As discussed in the methodological section, having sufficient number observations is a priority, since quality of fit, magnitude of bias and credibility of inference all depend on it. Nevertheless, it is not clear how many observations is "enough"[11]. Numbers of observations in current synthetic control literature on similar topics are summarized in Table 2.

[11] Annex to this thesis provides a rough estimate of decrease in estimator bias with increasing number of observations.

Table 2: Numbers of observations in literature using SCM

Literature	Number of pre-treatment periods	Number of post-treatment periods
Abadie et al. (2014)	30	13
Acemoglu et al. (2013) (daily stock prices)	250	100
ADH (2010)	18	12
Aytug (2014) (21 periods in total)	11-18	3-10
Campos (2014) (Eastern enlargement countries only)	11	4
Gomis-Porqueras and Puzzello (2015)	24	12
Jinjarak et al. (2013)	12	12

Current literature of SCM is not united in when series are “long enough”. The most prominent source on synthetic control methodology, the ADH (2010) paper uses 18 pre-intervention observations. From statistical perspective, this is low number. However the SCM is essentially about case studies where even small volume of observations may be reasonable. As for the post-intervention period Abadie et al. (2014) argue that approximately 10 years after German reunification is reasonably long period to observe the effects. As discussed in the methodological section (Assumption 6), this is more pressing issue when the treatment effect is expected to be gradual. It is likely the case of this thesis, since currency adoption effects take time to fully demonstrate and 3 years of post-intervention observations in the Estonian case without doubt do not include the whole impact of Euro. In practice the number of observations depends on data availability. Rarely do researches have the luxury of having such long series, that they can decide where to start. Although in such circumstances the choice of beginning of pre-intervention period may affect the results. Setting the intervention date is also not straightforward if we want to account for anticipation effects. Campos et al. (2014) predated EU-accession during the 2004 enlargement to 1998, to account for anticipation effects. This however increases the danger of confounding intervention effects with other effects, arising between the official intervention date and pre-dated one. Due to these concerns and short series this thesis settled with official Euro adoption dates as intervention date for estimation.

5.2 Control group pre-selection

Selection of set of controls that enter the estimations is the step with potentially the biggest impact on results. Current synthetic control literature on related topics serves as an inspiration:

- Abadie et al. (2014) restrict the sample to OECD countries when modelling synthetic Germany.
- Aytug (2014) included all candidate countries, potential candidate countries and EU members when estimating effect of Euro adoption on growth.
- Campos et al. (2014) use a very large sample of countries from all around the world to estimate effects of EU membership on income.
- Gomis-Porqueras and Puzzello (2015) estimate the effect of Euro adoption on income for six countries with a peculiar control group composed of Australia, Bahrain, Barbados, the UK, Norway, New Zealand, Singapore and USA.

We see rather large geographical spread in the literature. It is reasonable to assume that countries like Bahrain and Barbados experience very different shocks and are structurally very different from European economies. Also, when we use SCM to model Euro adoption, it should be controlled for the effect of EU membership, which may be substantial. This is best done by including mostly EU countries in the control sample or countries with significant spill-over effects from EU economies. Herein treated countries (Slovakia, Slovenia, Estonia, Malta, Cyprus) arguably bear more similarities with other European countries than rest of the world. Thus as a starting point, all European countries, with population at least 100 thousand (and Turkey) are considered.

All countries with the same intervention (Euro) should be excluded from estimation. Thus, all Eurozone members (apart from the countries of interest) are dropped from the dataset. Same applies to countries with currencies pegged to Euro and short time series. Next dropped are: Bosnia and Hercegovina, Kosovo and Montenegro. Then there are countries with links to Euro, but good time series, namely: Bulgaria, Croatia, Denmark and Baltic countries. The Baltic countries are a separate group. All three countries followed policy of currency stabilization through currency board since early 1990s. Lithuania chose peg to US dollar and later to Euro, Latvia pegged to SDR[12] first and Estonia pegged to German Mark. Both Lithuania and Latvia have been pegged

[12] Special Drawing Rights, basket of currencies used as IMF unit of account.

to Euro, since 2002 and 2005 respectively. Both introduced Euro in 2014/2015. An interesting counterfactual scenario would estimate the costs/benefits of Estonia adopting Euro three years ahead of its regional peers. So the three countries are only examined for that purpose. Croatian Kuna was left in the sample, despite being de facto pegged to Mark/Euro since its introduction. It was kept in a +/-6% fluctuation band which allowed some appreciation or depreciation. As of January 2015 it was decided that Kuna will be pegged to Swiss Franc for a while, so the peg to Euro is over. Bulgaria and Denmark provide dubious added value, are difficult to justify in the control sample and are thus left out. Other countries whose presence in the control sample is questionable are Iceland and Norway. Iceland is a specific island economy and Norway is a traditional outlier due to its oil income. As we discover later, these two countries may help satisfy convex hull condition, so for now these two countries stay in the sample. Table 3 provides shortlist of countries in the sample.

Table 3: Shortlist of countries, highlighted are treated countries

Country	Joined EU	Joined ERM II	Adopted Euro	note
Albania				
Croatia	2013			policy of keeping exchange rate vis-a-vis Euro stable until January 2015
Cyprus	2004		2008	
Czech Republic	2004			
Estonia	2004	2004	pegged since 1992/1999, adopted 2011	peg to German Mark, later to Euro
Hungary	2004			
Iceland				
Latvia	2004		pegged since 2005, adopted 2014	peg to SDR, later to Euro
Lithuania	2004	2004	pegged since 2002, adopted 2015	peg to US dollar, later to Euro
Macedonia				
Malta	2004	2005	2008	
Norway				
Poland	2004			
Romania	2004			
Serbia				
Slovakia	2004	2005	2009	
Slovenia	2004	2004	2007	
Sweden	1995			
Switzerland				
Turkey				
United Kingdom	1973			

Thus, at this stage there are 21 countries in the *full sample*. The sample is further divided into subsamples for comparison, there is a *control sample* – including only 16 control units, *Eastern European sample* – including 11 countries and *Western European Sample* – including only 5 western controls (two EU members). Summary statistics for all sample groups is provided in Table 16 in Appendix A.

What follows is a discussion of predictor variables which characterize the countries and relate to growth. After then, missing values and condition on hull convexity are briefly discussed and finally choice of final control groups will be explained.

5.3 Variable selection

Unlike control group selection, there is consensus about variables that should characterize the countries. This thesis does not deviate much from the rest of SCM literature on similar topics in variable selection. Two outcome variables are considered: *GDP per capita, adjusted for purchasing power parity, in international dollars*[13] (two possible sources) and *GDP growth rate*. The income per capita metric was also chosen by Abadie et al. (2014) and by Gomis-Porqueras and Puzzello (2015), in the latter case even for the same task – estimating effect of Euro adoption. Growth was chosen as outcome variable by Aytug (2014) for the exact same task, so the results can be directly compared.

Predictor variables should characterize the economies. Nine variables are initially considered. Again, the same uncontroversial growth predictions as in the aforementioned papers are used: *Investment rate, Secondary school enrolment, Share of industry value added* and *Trade openness ratio*. Variable controlling for government finances - *Government expenditure* is a new addition. Another addition is variable controlling for demographic structure: *Age dependency ratio*. Since population growth rate is implicitly included in the per capita outcome, population growth variable is redundant. Because currency policy heavily impacts a country's external balance, *Current account balance* is also included. Last addition is a traditional measure of development: *Infant mortality rate*. The reasoning for the last variable stems from high level of healthcare in Eastern Europe relative to income. The data sources are publicly

[13] Also called "Income per capita" throughout this paper.

available WB and IMF databases.[14] See Table 4 for detailed description of variables and sources.

Table 4: Variable description and sources

Variable	Description	Source
GDP_pc_WB	GDP per capita, PPP (constant 2011 international $)	WB
GDP_pc_IMF	GDP per capita, PPP (constant 2002 international $)	IMF
GDP_growth	GDP growth (%)	IMF
School_enrol	School enrollment, secondary (% gross)	WB
Industry_va	Industry, value added (% of GDP)	WB
Inflation	Inflation, consumer prices (annual %)	IMF/WB
Trade	Trade (% of GDP)	WB
Gov_exp	General government final consumption expenditure (% of GDP)	WB
Age_dep	Age dependency ratio, young (% of working-age population)	WB
Infant_mortality	Mortality rate, infant (per 1,000 live births)	WB
Investment	Total investment (% of GDP)	IMF
Current_account_balance	Current account balance (% of GDP)	IMF

5.4 Missing values

The dataset starts in 1990, many countries however have data available from a later date. Occasionally there are missing predictor values in the middle of the observed period. Statistical software usually handles missing outcome values in panel data by dropping the all observations in the period where an input of just one unit is missing. A balanced dataset is thus strongly desirable. Overview of missing values is provided in Appendix B, Tables 24-26. As apparent, former-Yugoslav countries have a high share of missing values in 1990s. They are candidates for being excluded from the dataset in case it conflicts with maximizing length of observed period. In the extreme case of Macedonia, information on investment share of GDP is completely missing. From periodical perspective, most missing values concentrate into the first five observation years, which corresponds to new countries emerging during that period. The dataset can be truncated to start later than 1990 to exclude poor quality data at the beginning, at the cost of series length. There are techniques to approximate the missing values (Schafer and Graham, 2002, provide overview of those techniques), however those techniques rely on large sample statistical properties and therefore are not applied here.

[14] World Bank source at: http://databank.worldbank.org/data/ and IMF source at: http://data.imf.org/

5.5 Hull convexity

Appendix B provides information on violations of the convex hull assumption. Figures 17 and 18 compare how well do full control and East European Control sample cover the whole range of variable values of the treated units. Compared to East European controls, the treated units are on the rich end of the income spectrum which makes control sample restricted to Eastern Europe difficult if not impossible to use. Table 28 highlights treated countries and variables which lie outside the convex hull. Three treated countries – Slovenia, Malta and Cyprus - lie outside the convex hull of the Eastern European controls in terms of income per capita. This is a strong argument for inclusion of Western European countries in the control sample or using growth rates instead of GDP per capita levels as outcome variable for the three countries. No outcome variable lies outside the convex hull of Full sample, which means that Assumption 5 can be satisfied and all countries can be estimated. As for predictor variables, Trade Openness lies outside the convex hull in all cases for Estonia, Slovakia and Malta. This is due to export oriented nature of these economies. Other cases of unavoidable violation of hull convexity are: Malta-Share of industry value added, Slovenia-Age dependency ratio and Estonia-Share of investment to GDP. In all cases the values are higher than control sample. These were cases where hull convexity could not be improved by including Western European countries in the control sample. Apart from that there is a number hull convexity violations if the control sample is restricted only to Eastern Europe. Only Slovakia fits within the range provided by Eastern control sample, hence it can be modelled using only the tighter group of controls.

5.6 Dataset composition

Now we have a three-dimensional data selection problem: finding the optimal combination of countries, years and variables. This is a non-trivial task since in most cases we have to choose between number of countries in the control sample and number of variables or number of observations. The reason behind this is how SCM treats missing values. The algorithm averages all observations of one variable for a country, if there are no observations, there is no average. First, any missing value in the outcome variable renders that whole period (year in our case) across dataset useless. This means there is often a trade-off: including a country or including extra year of observations. Second, if a predictor variable is missing for all periods for any country it cannot be used. Third, if a predictor variable is missing for all countries in one period, that period cannot be included in the estimation. The last issue causes only lower precision of matching, but it can be managed by specifying over which period the average should be calculated.

In this thesis the problem is approached by constructing all meaningful combinations of countries, predictors and periods and picking one with sufficiently low RMSPE. There are two reasonable periods when to start the observation: 1992 and 1995. This is given by data availability in Eastern Europe. It means increasing the potential number of datasets twofold. Then there is a conflict between Macedonia and Investment predictor, accounting for all combinations increases the number of potential datasets twofold again. Then there is the choice of Full control sample vs. Eastern Europe sample, however as we discussed in previous section on hull convexity, Eastern sample is only applicable in Slovak case. Lastly, there is selection of outcome variable. For most countries GDP per capita at PPP from World Bank source is the longest outcome series available and therefore it is preferred to IMF GDP per capita, PPP source. Growth rates are also estimated as outcome variable, so there are two possible outcome variables in each dataset. In total there are up to 2^4=16 possible datasets for each treated country. In order to choose a good modelling dataset, three factors are considered (in this order of importance):

1. restriction to smaller sub-sample (Eastern Europe, Baltics) to reduce interpolation bias if possible
2. maximum number of observation periods, countries and predictors possible
3. minimum RMPSE ratio

The third is a quantitative measure. Each dataset produces pre-intervention RMSPE. In order to compare the RMSPEs across different outcome variables, a ratio of the pre-intervention RMSPE to average of pre-intervention outcome variable is calculated. The order of importance reflects intuitive reasoning in the first place, data quality with respect to requirements of SMC in the second and goodness of fit in the third. This is of course at author’s discretion and is thus subject to bias, however it satisfies the purpose of establishing a clear procedure of control dataset selection.

6 Results

Overview of estimated country weights is presented in Tables 5 and 6 at the beginning of the section. Country specific inference and discussion of results is presented per country in the rest of the section. For each country first predictors are reported, then estimated country weights with robustness checks and finally the synthetic series. Whenever possible both income per capita and growth were estimated. Whenever weights of given treated country are sufficiently robust to control sample composition, leave-one-out check for stability of treatment effect is performed (Figures 14-16 in Appendix A).

Table 5: Country weights where outcome variable is GDP per capita

Outcome variable: Income per capita				
Controls\Treated	Slovakia	Slovenia	Malta	Cyprus
Albania	0	0	0	0.264
Croatia	-	0.032	-	-
Czech Republic	0.299	0.558	0	0
Hungary	0.246	0.2	0	0
Iceland	-	-	0	0
Latvia	-	-	-	-
Lithuania	-	-	-	-
Macedonia	0	-	-	-
Norway	-	-	0.19	0
Poland	0.117	0	0.714	0
Romania	0.338	0	0	0
Serbia	-	-	-	-
Sweden	-	0.209	0	0
Switzerland	-	0	0.039	0.128
Turkey	-	-	0.057	0
United Kingdom	-	-	0	0.608

Table 6: Country weights where outcome variables are growth rates

Outcome variable : GDP growth				
Controls\Treated	Slovakia	Slovenia	Estonia (only Baltics)	Cyprus
Albania	0	0	-	0.261
Croatia	-	0	-	0
Czech Republic	0.226	-	-	-
Hungary	0.004	0.433	-	0.362
Iceland	-	-	-	0
Latvia	-	-	0.827	-
Lithuania	-	-	0.173	-
Macedonia	0.267	0	-	0
Norway	-	-	-	0
Poland	0.333	0.542	-	0
Romania	0.17	0.025	-	0
Serbia	-	-	-	-
Sweden	-	0	-	0.14
Switzerland	-	0	-	0.237
Turkey	-	0	-	0
United Kingdom	-	0	-	0

6.1 Slovakia

In the case of Slovak income per capita matching, control sample restricted to Eastern Europe was sufficient for a good match. Predictor variable averages of the observed series are close to synthetic, exceptions being trade and inflation (Table 17 in Appendix A). Slovakia's trade openness as strongly export oriented economy could not be reproduced with the control group. Inflation of the synthetic stands out due to relatively high weights of Romania and Hungary – two countries with high inflation in the 1990s.

Country weights are reported in Tables 5 and 6. The weights are rather evenly divided among the Czech Republic, Poland, Hungary and Romania when income is the outcome variable. When growth series are being matched, weight of Hungary is replaced by Macedonia. In both cases, weight of Hungary is not robust, it drops to zero when the control sample is restricted to countries with positive weights, as visible from Tables 7 and 8. The robustness of Macedonian weights in growth matching is also low, it drops to zero when Romania is left out, see Table 8. Polish and Czech weights are stable when other control units are removed. Hence it is feasible to construct synthetic Slovak series for income and growth with reasonable weights. All countries are from the

Eastern European sample, most are EU members and should be subject to similar shocks.

Table 7: Synthetic weights for combinations of control countries, Slovakia, Income

Slovakia, Income matching			
Combinations of control countries			
Poland	Czech Republic	Romania	Hungary
0.549	0.357	0.094	0
Poland	Czech Republic		
0.673	0.327		

Note: In each row country with the lowest weight (in the rightmost column) is removed, sometimes weights change even if the removed country had zero weight. Same applies to all following weight tables.

Table 8: Synthetic weights for combinations of control countries, Slovakia, Growth

Slovakia, Growth matching				
Combinations of control countries				
Poland	Czech Republic	Macedonia, FYR	Romania	Hungary
0.211	0.411	0.277	0.101	0
Poland	Czech Republic	Macedonia, FYR	Romania	
0.221	0.391	0.348	0.039	
Poland	Czech Republic			
0.599	0.401			

Real and synthetic series are presented in Figures 5 and 6. Vertical dashed lines indicate EU entry and the end of pre-treatment period for official Euro adoption. Slovakia started diverging from its synthetic control as early as 2004 – the EU entry year. This is confirmed by RMSPE test, Table 22 in Appendix A reports the post-intervention to pre-intervention ratio of RMSPE for the official Euro adoption year and for 2004. There is no sizeable difference between the two for neither income nor growth. This means we cannot attribute the post-intervention (post 2008) gap between real series and synthetic series to the 2008 Euro adoption.

Figure 5: Slovakia vs. Synthetic Slovakia, Income

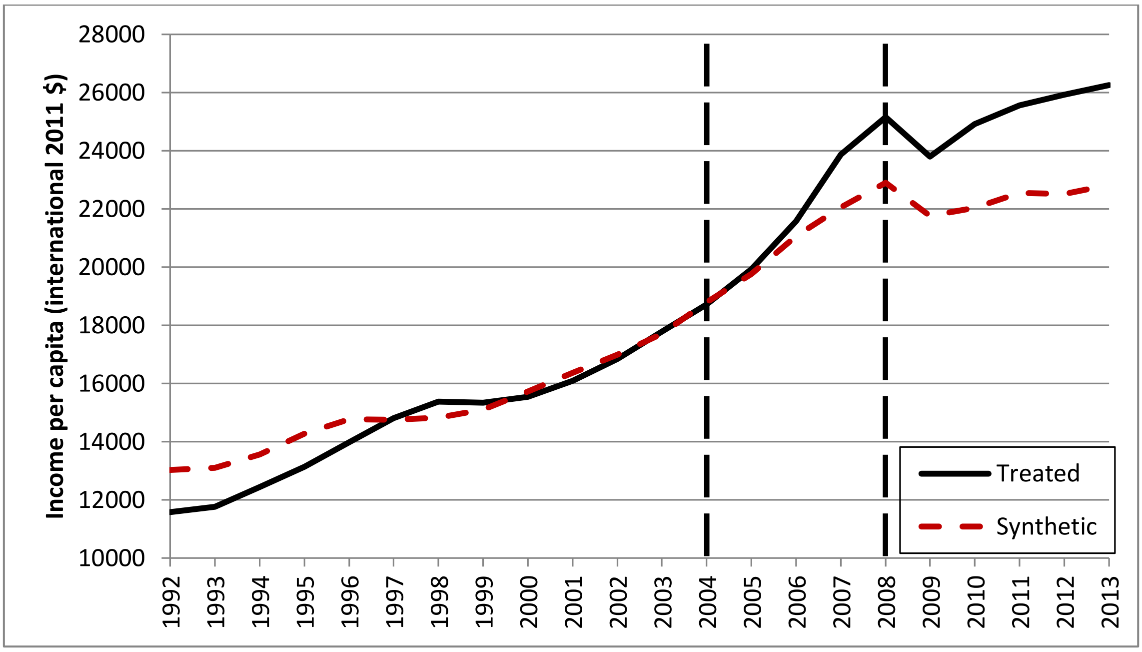
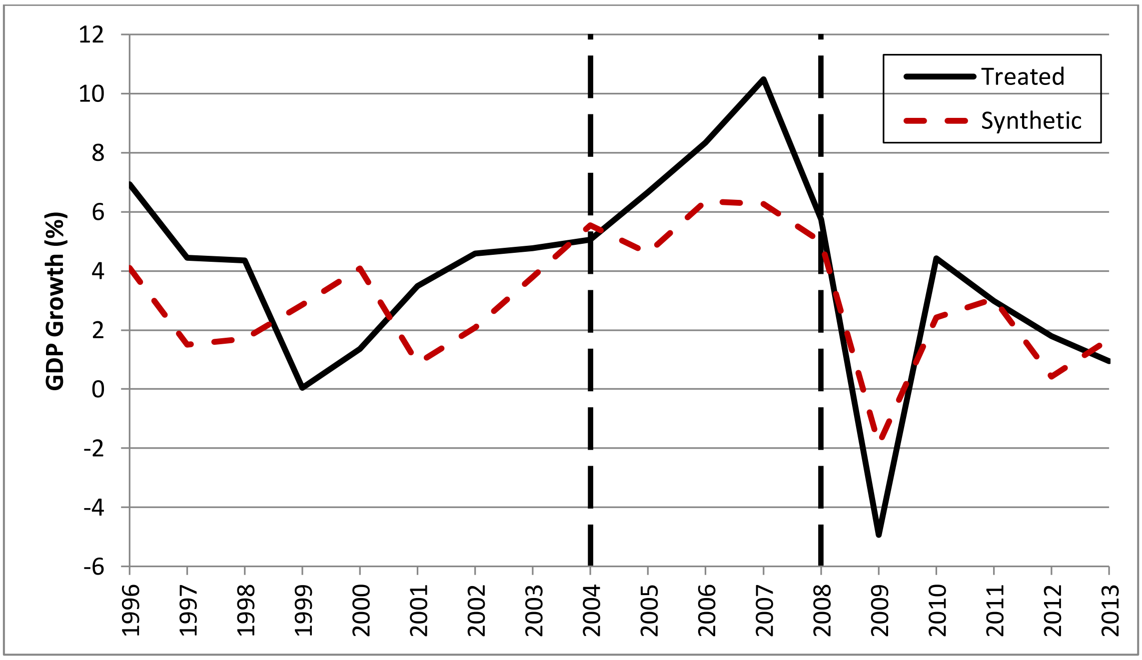


Figure 6: Slovakia vs. Synthetic Slovakia, Growth



In the crisis years synthetic Slovakia performed better than real Slovakia. This would be a case against prevailing public opinion in the Slovak Republic – which holds that Euro helped stabilize economy during the crisis. On the contrary, the result is in line with Torój (2012) DSGE counterfactual simulation, where Slovak exports were depressed more than those of regional peers. According to Fidrmuc and Korhonen

(2013), Slovakia fixed its exchange rate to Euro at rather over-appreciated value. This forced internal devaluation to restore external competitiveness, which may be the reason for the hefty decline in income and growth in the first years, compared to synthetic. However after the crisis, real Slovakia rebounded much faster than its synthetic counterpart. It is unclear however how much of this growth can be attributed to Euro and how much to structural changes during the crisis. Compared to Aytug (2014), who also estimated growth effect with the same methodology, this thesis arrived at different weights, but similar synthetic growth series.

6.2 Slovenia

Matching Slovene income per capita requires inclusion of Western European countries in the control sample to account for hull convexity. In our case Sweden took the positive weight. Predictor averages are well matched by the synthetic, the only outlier being current account balance as percentage of GDP. The averages are reported in Table 18 in Appendix A. Table 5 reports country weights for income matching. The biggest donor with 0.558 weight is the Czech Republic, Sweden and Hungary weight about 0.2 and Croatia has small weight of 0.032. Table 9 reports robustness check. Robustness of all weights is very low, reducing the sample changes weight composition substantially. Hence we can make no conclusions based on income matching alone.

Table 9: Synthetic weights for combinations of control countries, Slovenia, Income

Slovenia, Income matching			
Combinations of control countries			
Czech Republic	Sweden	Croatia	Hungary
0.609	0.223	0.168	0
	Sweden	Croatia	
	0.363	0.637	

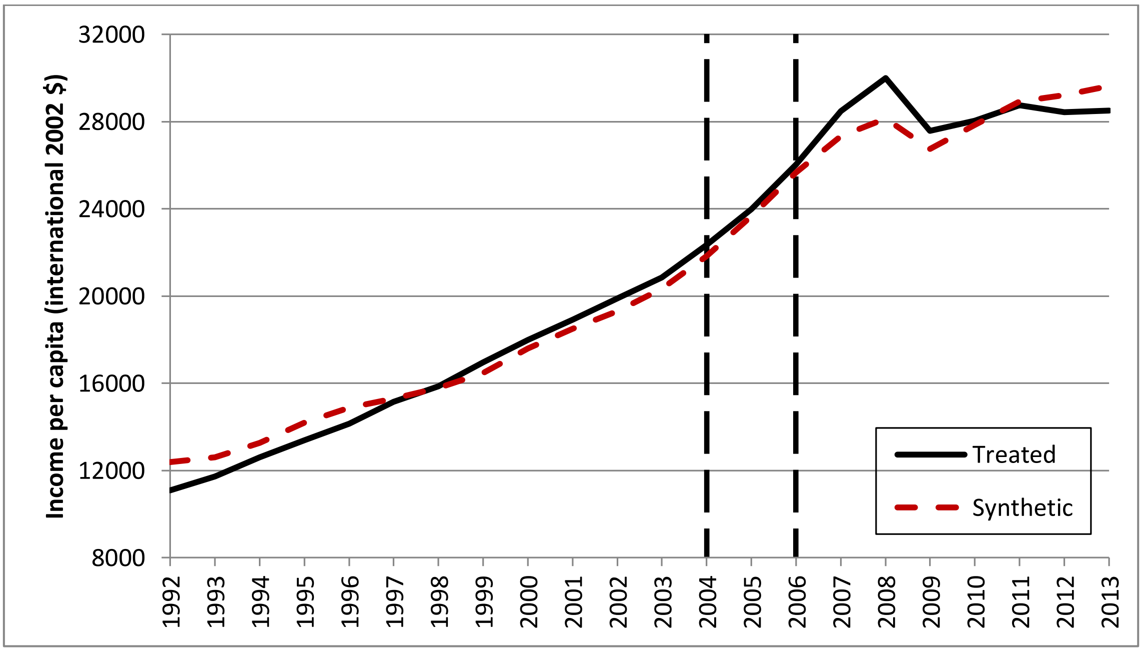
When the outcome variable is growth, the synthetic can be composed of countries from the same region. Table 6 reports the full sample weights, Table 10 reports weights for countries with positive weight. In both cases Poland and Hungary are about equally important donors (0.542 and 0.433 respectively), Romania complementing (0.025). The weights are robust to changes in the control sample. Matching growth series is more reliable in the Slovene case than matching income, and accordingly, inference from growth matching is more reliable.

Table 10: Synthetic weights for combinations of control countries, Slovenia, Growth

Slovenia, Growth matching		
Combinations of control countries		
Poland	Hungary	Romania
0.542	0.433	0.025
Poland	Hungary	
0.544	0.456	

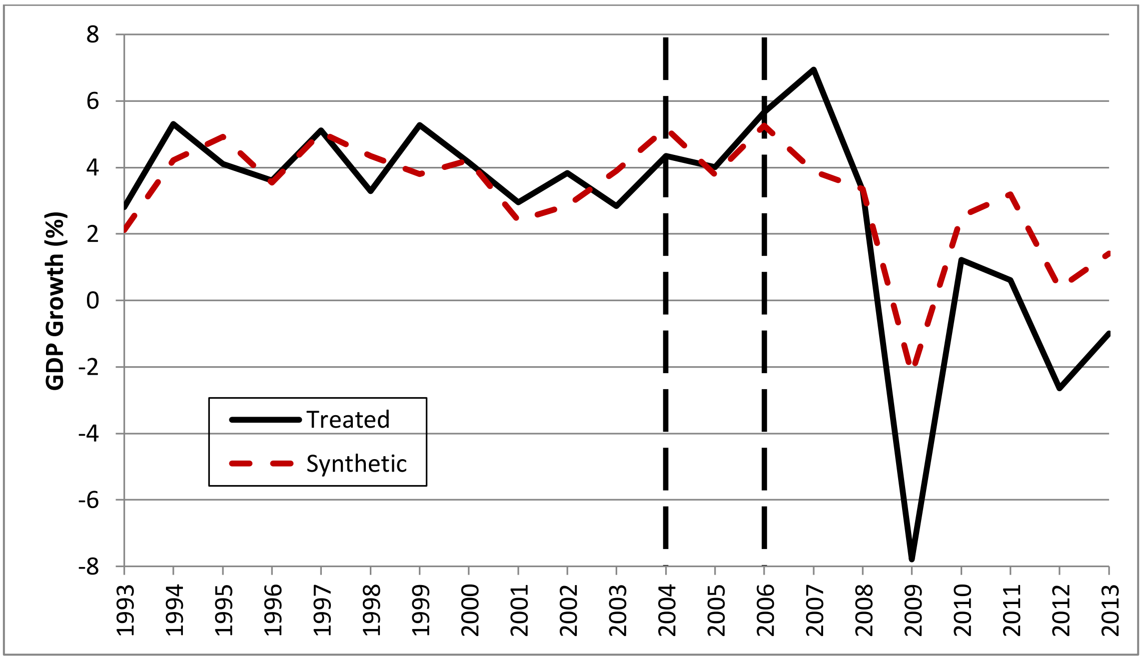
The real and synthetic income series are plotted in Figure 7. There is visible difference between synthetic and real Slovenia after Euro adoption, although RMSPE check is inconclusive (Table 22 in Appendix A). Slovenia outperformed its synthetic in the pre-crisis years, but suffered more during the crisis and was outpaced by the synthetic afterwards. The result is unreliable due to the low robustness of weights.

Figure 7: Slovenia vs. Synthetic Slovenia, Income



Real and synthetic growth series are plotted in Figure 8. It tells the same story as income. Slovenia outperformed pre-crisis, but declined more severely during the crisis and started lagging afterwards compared to synthetic control; compared to income matching with very different (and more robust) composition of the synthetic. Leaving one control country out does not invalide the result (Figures 14 and 15 in Appendix A). Compared to Aytug (2014), the post-intervention gap between synthetic and real growth series is bigger, the weight composition also differs as in Aytug's paper Iceland weights more than 50%, here it does not attain positive weights at all.

Figure 8: Slovenia vs. Synthetic Slovenia, Growth

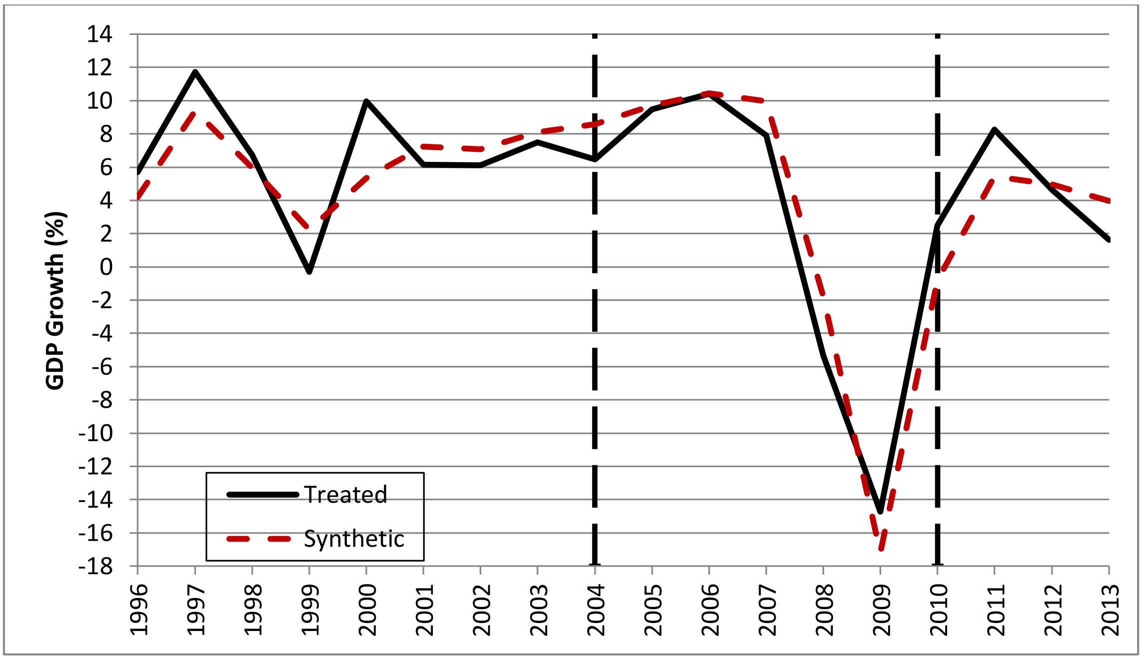


6.3 Estonia

Estonian currency had been pegged to Euro until 2011, when the country joined Eurozone. Latvia adopted Euro four years later and Lithuania year after that in 2015. All three countries followed a policy of stabilizing their currencies by pegging to Mark/Euro in Estonian case, US dollar in Lithuanian and SDR in case of Latvia. In 2004 Estonia and Lithuania joined ERM II, Latvia followed in 2005 (maintaining very narrow +/-1% ER band). The three countries are economically very similar and are thus suitable for case study comparisons. Here synthetic Estonia is created using the other two countries' series until 2011. First purpose of this little exercise is to derive weights as measure of similarity to the control countries; second is to estimate the effect of introducing Euro three years ahead of the other two countries.

Estimating income proved to be technically difficult, so only growth matching is presented. Table 19 in Appendix A reports predictor averages, as expected the sample is rather homogenous. Synthetic Estonian weights were estimated as 0.827 for Lithuania and 0.173 for Latvia. So in terms of growth rates the country arguably bears more similarity with Lithuania. The quality of matching Estonian growth with the regional peers is rather good since all three countries are exposed to the same shocks. Figure 9 reports the original and synthetic series. There is no significant difference between synthetic and real series in the post-intervention years 2011-2013, compared to pre-intervention years.

Figure 9: Estonia vs. Synthetic Estonia, Growth



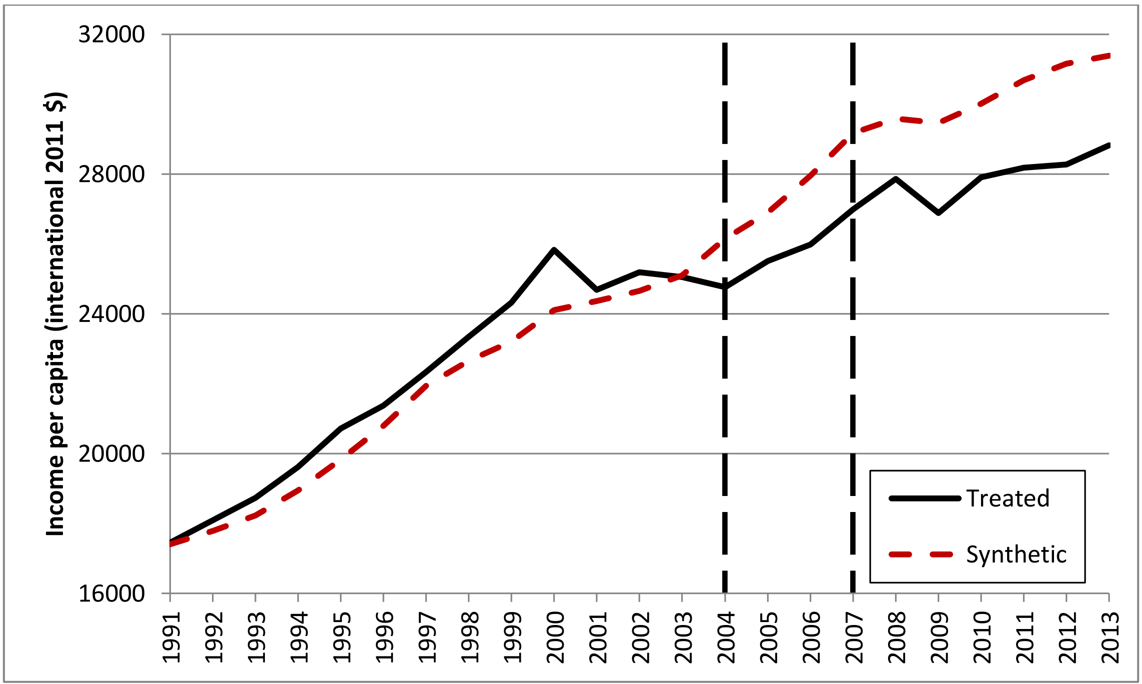
6.4 Malta

Malta is a very specific economy and difficult to match synthetically. Synthetic income series weight Poland heavily, followed by Norway, Turkey and Switzerland. All these countries arguably bear few similarities to Maltese economy and the interpolation bias is likely to be strong in this match. While weights are rather robust to control sample selection (Table 11), the fit itself is very poor (Figure 10). We cannot infer any conclusions from these results.

Table 11: Synthetic weights for combinations of control countries, Malta, Income

Malta, Income matching			
Combinations of control countries			
Poland	Norway	Turkey	Switzerland
0.582	0.135	0.173	0.11
Poland	Norway	Turkey	
0.707	0.222	0.071	
Poland	Norway		
0.78	0.22		

Figure 10: Malta vs. Synthetic Malta, Income



6.5 Cyprus

Cyprus is an island economy with a number of structural differences from the control group. A number of predictors are not well matched by the control group (Table 21 in Appendix A). The estimated weights put Cypriot income between Albania, Switzerland and United Kingdom (Table 5) and are robust to control group selection (Table 12). This is obviously strong interpolation, nonetheless the income series is matched well by the synthetic (Figure 11) and robust to weigh changes (Figure 16 in Appendix A). Growth series matching is less robust to control group selection (Table 13). And although growth is also well matched (Figure 13), it should be interpreted with caution.

Table 12: Synthetic weights for combinations of control countries, Cyprus, Income

Cyprus, Income matching		
Combinations of control countries		
United Kingdom	Albania	Switzerland
0.48	0.312	0.208
United Kingdom	Albania	
0.81	0.19	

Table 13: Synthetic weights for combinations of control countries, Cyprus, Growth

Cyprus, Growth matching			
Combinations of control countries			
Sweden	Albania	Hungary	Switzerland
0.841	0.159	0	0

There is visible divergence of the real and synthetic Cyprus since 2009 in both income and growth (Figure 12). Although it is not confirmed by RMSPE check (Table 22 in Appendix A) due to short series. The cumulative difference between real and synthetic Cypriot income per capita in is -9012 (2011 international dollars), over the 2008-2013 period. This was about 33% of GDP per capita of Cyprus in 2013. In the case of Cyprus the post-2008 underperformance may also be explained by bad government policy over the past five years. Orphanides (2014) identifies government approach to public finances and banking system as the most significant contributor to Cypriot decline. Whether or not that was the case, we do not find strong case for Euro in Cyprus with synthetic control approach.

Figure 11: Cyprus vs. Synthetic Cyprus, Income

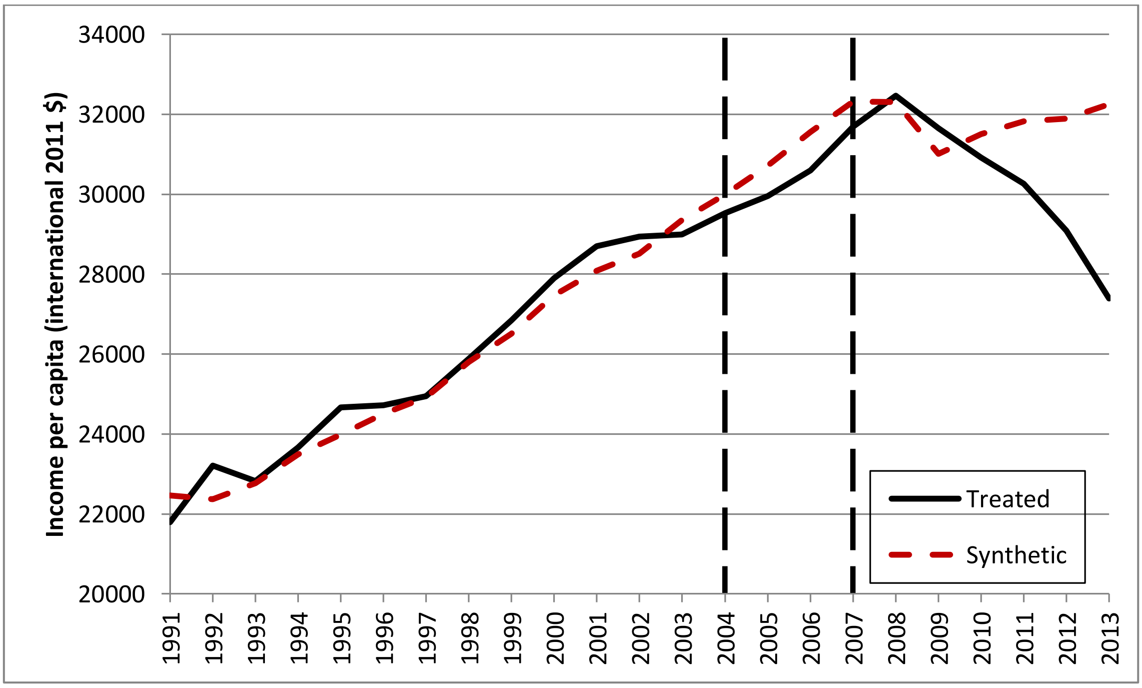
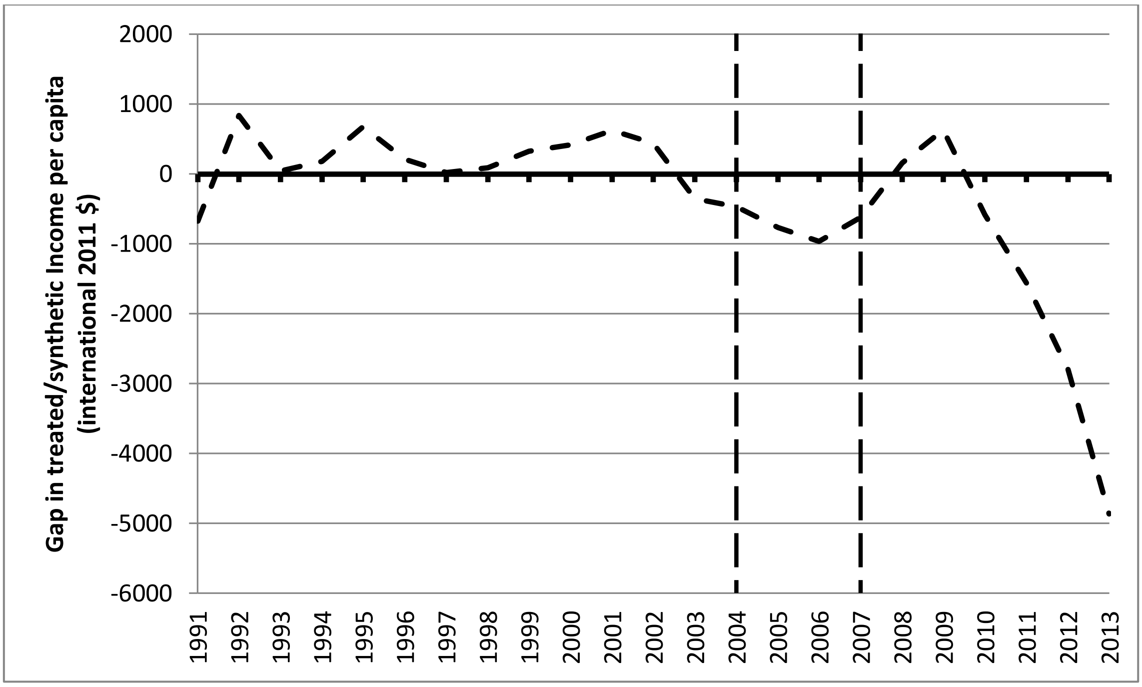
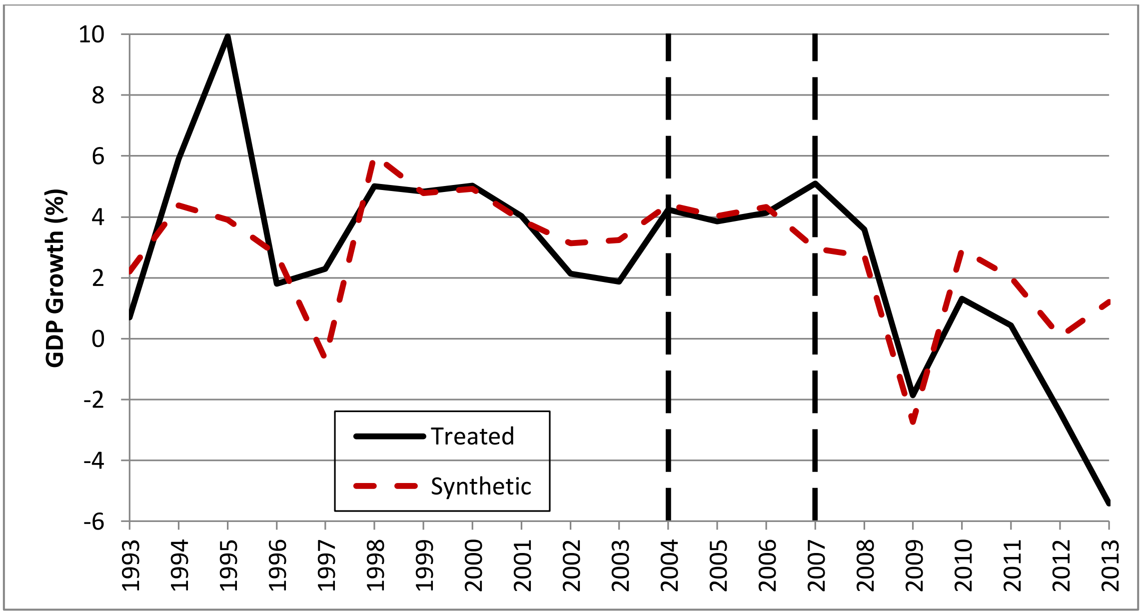


Figure 12: Gap between Cyprus and Synthetic Cyprus, Income



Aytug (2014) also estimated growth with SCM and arrived at similar weight composition and a plot similar to Figure 13.

Figure 13: Cyprus vs. Synthetic Cyprus, Growth



6.6 Results summary

Results per country and outcome variable are summarized in Table 14. Estimated weights and intervention effects are more conclusive for Slovenia and Cyprus, less for Slovakia and indecisive for Malta due to poor matching. Estonia was only matched with two countries (Lithuania, Latvia) so robustness is not an issue.

Table 14: Summary of estimation results

	Outcome variable	Weight robustness	Match quality	Estimated Euro effect	
				during crisis	after crisis
Slovakia	income	low	high	negative	positive
Slovakia	growth	low	low	inconclusive	inconclusive
Slovenia	income	low	high	negative	negative
Slovenia	growth	high	high	negative	negative
Estonia (only Baltics)	growth	high	high	-	neutral
Malta	income	high	low	inconclusive	inconclusive
Cyprus	income	high	high	neutral	negative
Cyprus	growth	low	high	neutral	negative

Table 15 reviews results from literature on similar topics which also applied synthetic control method. Comparability with this thesis is limited as Campos et al. (2014) studied different effect and Aytug (2014) only used data until 2011, which effectively means only 3-4 years of post-intervention observations. Aytug has the same direction of the effect for Slovenia (negative) and Malta (indecisive with very poor match quality). His estimated effect on Slovakia is neutral, also rather similar to result of this thesis. For Cyprus the estimated effect is opposite (positive) of this thesis (negative). However, in this thesis the divergence between Cypriot real and synthetic series develops after 2010 and in Aytug (2014) the observation period was limited by 2011, so the results do not necessarily contradict each other.

Table 15: Comparison of results in similar literature

Source and estimated effect	Country	Estimated effect
Campos et al. (2014): Effect of EU entry on GDP	Slovakia	mild positive
	Slovenia	strong positive
	Estonia	strong positive
	Malta	-
	Cyprus	-
Aytug (2014): Effect of Euro adoption on GDP growth (only until 2011 - includes mostly crisis years)	Slovakia	neutral
	Slovenia	negative
	Estonia	-
	Malta	neutral/indecisive
	Cyprus	positive

6.7 Further research opportunities

Future methodological research may focus on establishing a formal framework for measuring bias of synthetic control estimators and finding minimal threshold for length of observation period. A meta-analytical work in this field would be beneficial. When the volume of literature on similar topics using synthetic controls builds up, it will be interesting to see comparison of synthetic weights estimated for each country. Supporting insufficient inference from synthetic counterfactuals with other empirical techniques would help validate the results. Lastly, when more post-intervention observations are available it will be interesting to extend the estimated results to get long term effects.

7 Conclusion

First task of this thesis was to review synthetic control methodology and its applicability for the case of short eastern European time series. The available time series are generally deficient in length, nonetheless they allow for good matching in some cases. Compared to other synthetic control literature the number of yearly observations from first available data to Euro introduction is on the low end. Despite the fact, some countries can be matched acceptably within their regional control group, satisfying most assumptions of the synthetic controls. However the inference techniques commonly used with synthetic control still succumb to the small sample and short series and often do not provide meaningful inference. It may improve with longer post-intervention series over time though.

Treatment effect of Euro adoption was estimated for Slovakia, Slovenia, Estonia, Malta and Cyprus on GDP per capita at PPP and GDP growth rate. The estimated results are to be interpreted with caution due to often low robustness of estimated synthetic weights and due to short post-intervention series. In case of Slovakia and Slovenia the synthetic counterparts experienced stronger decline than the real countries during the crisis years, indicating that Slovakia and Slovenia might have been better-off without Euro during the crisis. In Slovak case the post crisis recovery was stronger than that of synthetic match, in Slovene case the opposite was observed. However, this may be result of structural changes in the economies during the crisis, rather than effect of Euro. Note also that significance of the intervention date for Slovakia was invalidated by RMSPE check. Estonia was compared to Lithuania and Latvia during 2011-2013. There was no significant effect on growth when the country adopted Euro relative to its peers. As for the Mediterranean islands, Maltese match was insufficient for inference, Cyprus declined severely after crisis, whereas synthetic Cyprus kept growing after brief decline in 2009, although at a slower pace. The cumulative difference of the real and synthetic Cypriot GDP per capita at PPP over the period 2008-2013 was about (minus) 9,000 international dollars or 33% of Cypriot GDP per capita in 2013. However the Euro effect is inseparable from the effects of banking crisis and government policy in Cyprus and real costs of Euro may thus be significantly lower.

Overall the estimated effects of Euro adoption were neutral to negative for selected countries, and hence support the stream of literature critical of the immediate economic benefits of Euro adoption for new EU members. The decisiveness of results was adversely affected by data quality however. Prospective Eurozone members might reconsider timing of Euro adoption. For countries already pegged to the common currency in some way, Euro adoption may not have large impact. Countries with independent, floating currencies might face higher costs than benefits over the short term. The long term effects are still to be observed.

8 Appendix A

Table 16: Descriptive statistics summary

	Control sample			Western Europe Sample			Eastern Europe sample			Full sample		
Variable	# observations	Mean	Std. Dev.	# observations	Mean	Std. Dev.	# observations	Mean	Std. Dev.	# observations	Mean	Std. Dev.
GDP_pc_WB	373	23 283.39	15 106.65	120	42 146.10	10 689.71	361	16 924.80	6 910.43	481	23 217.01	13 546.18
GDP_pc_IMF	354	20 105.61	13 471.62	120	34 714.18	11 985.89	336	14 929.57	7 181.25	456	20 136.04	12 313.00
GDP_growth	354	2.46	4.60	120	2.14	2.39	332	2.83	5.04	452	2.65	4.50
School_enrol	340	94.48	14.93	112	106.97	13.91	333	89.59	10.52	445	93.97	13.71
Industry_va	346	30.74	6.30	112	29.60	5.39	331	31.86	7.31	443	31.29	6.94
Inflation	364	23.00	94.39	120	2.71	2.62	354	24.65	95.60	474	19.10	83.15
Trade	369	80.89	28.04	120	74.97	17.74	354	97.57	37.74	474	91.85	35.20
Gov_exp	368	18.27	4.99	120	19.93	5.03	353	17.91	4.19	473	18.42	4.50
Age_dep	384	30.06	8.07	120	29.01	3.85	384	29.68	8.50	504	29.52	7.66
Infant_mortality	384	11.25	9.48	120	4.14	1.36	384	12.20	9.02	504	10.28	8.61
Investment	338	21.96	5.40	120	20.03	3.76	325	23.46	5.86	445	22.54	5.59
Current_account_balance	358	-2.33	7.18	120	2.87	8.07	345	-4.76	4.89	465	-2.79	6.75

Table 17: Predictor averages, Slovakia

Slovakia	Predictor averages			
	Income		Growth	
	Treated	Synthetic	Treated	Synthetic
school_enrol	89.40235	89.39442	89.71964	89.72435
industry_va	36.11017	35.90399	36.05521	34.16385
inflation	6.925867	27.88393	6.194846	9.897847
trade	128.285	86.07387	131.3439	84.42341
gov_exp	20.11232	17.04535	19.31887	17.43319
age_dep	28.89602	25.77239	26.71634	26.71235
infant_mortality	10.43529	13.11487	9.515385	11.08662
current_account_balance	-5.875812	-5.475783	-7.341231	-5.229602

Table 18: Predictor averages, Slovenia

Slovenia	Predictor averages			
	Income		Growth	
	Treated	Synthetic	Treated	Synthetic
school_enrol	92.65533	99.83935	93.08907	96.44668
industry_va	34.97011	34.71549	34.97011	32.67015
inflation	9.818071	9.65995	9.818071	13.82263
trade	103.924	90.91054	103.924	79.14346
gov_exp	18.32331	21.80575	18.32331	20.24254
age_dep	23.69636	25.57222	23.3256	27.32781
infant_mortality	5.06	6.8746	4.871429	9.920893
investment	25.34733	25.32575	-	-
current_account_balance	-0.4887333	-2.915768	-0.9281428	-5.107184

Table 19: Predictor averages, Estonia

Estonia	Predictor averages	
	Growth	
	Treated	Synthetic
school_enrol	100.2093	96.96836
industry_va	29.05482	24.9676
inflation	6.149733	5.735809
trade	124.9817	102.0616
gov_exp	18.84443	20.09818
age_dep	25.09145	24.83153
infant_mortality	7.253333	12.01185
investment	31.06087	26.39814
current_account_balance	-8.274667	-8.282932

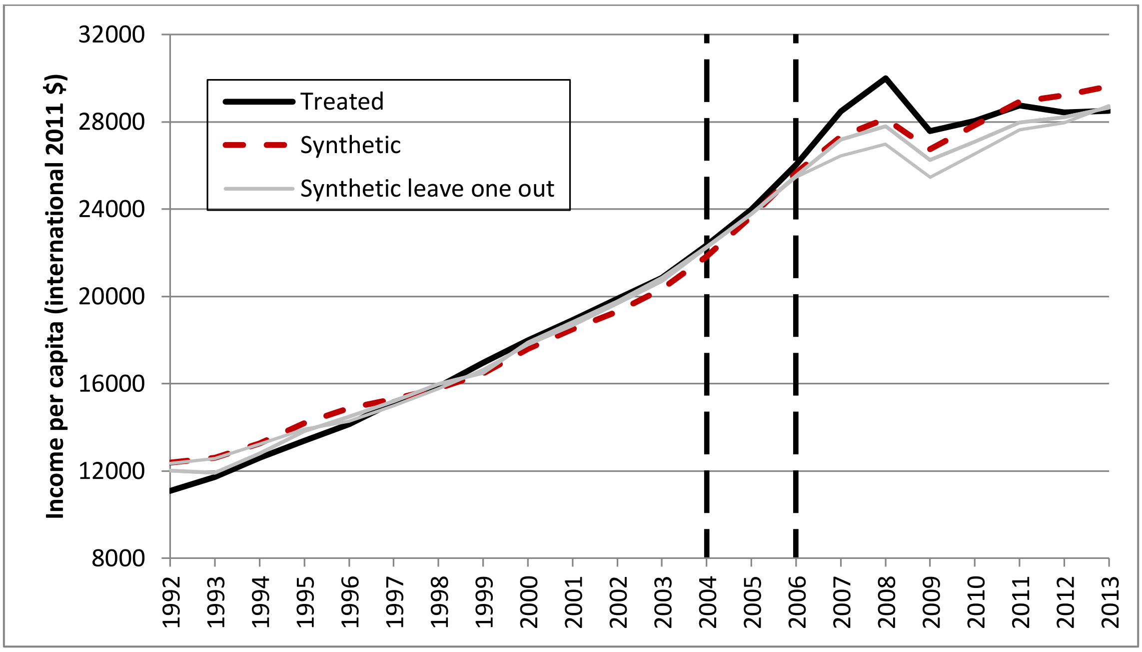
Table 20: Predictor averages, Malta

Malta	Predictor averages	
	Income	
	Treated	Synthetic
school_enrol	83.80854	98.97835
industry_va	45.90733	33.75532
inflation	2.765529	15.74228
trade	169.65	60.54457
gov_exp	19.09148	19.09809
age_dep	30.87989	30.8755
infant_mortality	7.329412	9.980141
investment	20.64092	20.80476
current_account_balance	-6.2	-0.614721

Table 21: Predictor averages, Cyprus

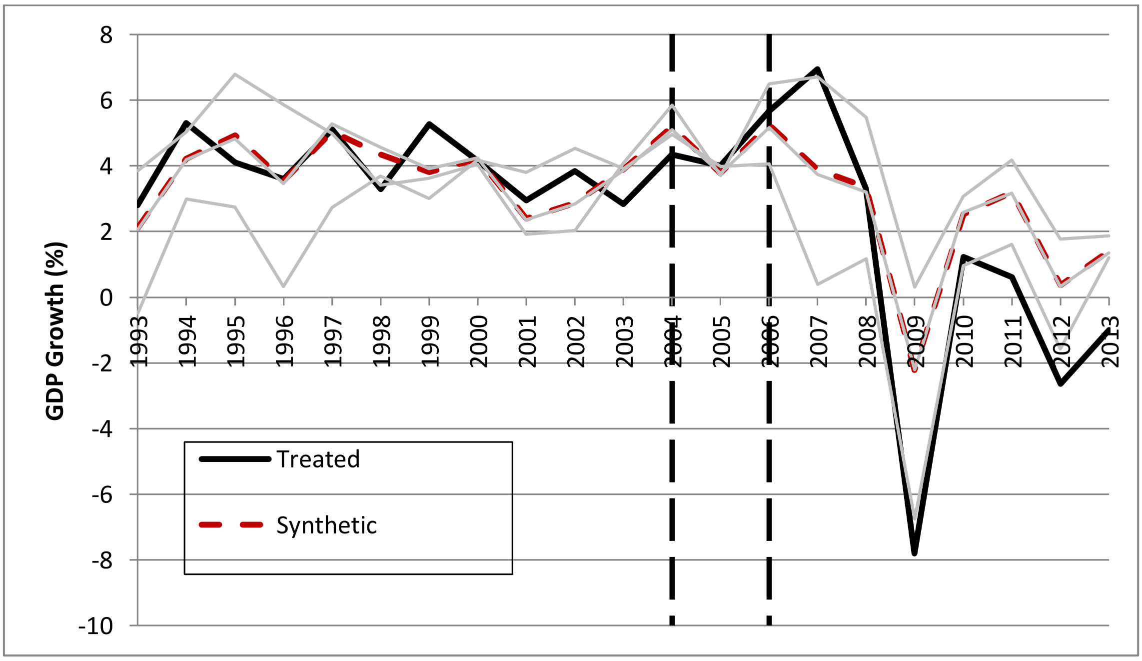
Cyprus	Predictor averages			
	Income		Growth	
	Treated	Synthetic	Treated	Synthetic
school_enrol	91.65524	91.64991	95.24391	93.83234
industry_va	21.17262	25.57952	20.50901	27.31941
inflation	3.237176	8.806132	2.8994	8.50242
trade	102.0494	59.42835	101.3709	87.94598
gov_exp	17.26969	15.88638	17.07263	17.04044
age_dep	33.79125	33.45984	33.08015	31.20414
infant_mortality	6.264706	10.65831	5.833333	11.27689
investment	21.14335	19.61358	-	-
current_account_balance	-4.062706	-1.135912	-3.489	-0.7430424

Figure 14: Leave-one-out weight robustness check, Slovenia, Income



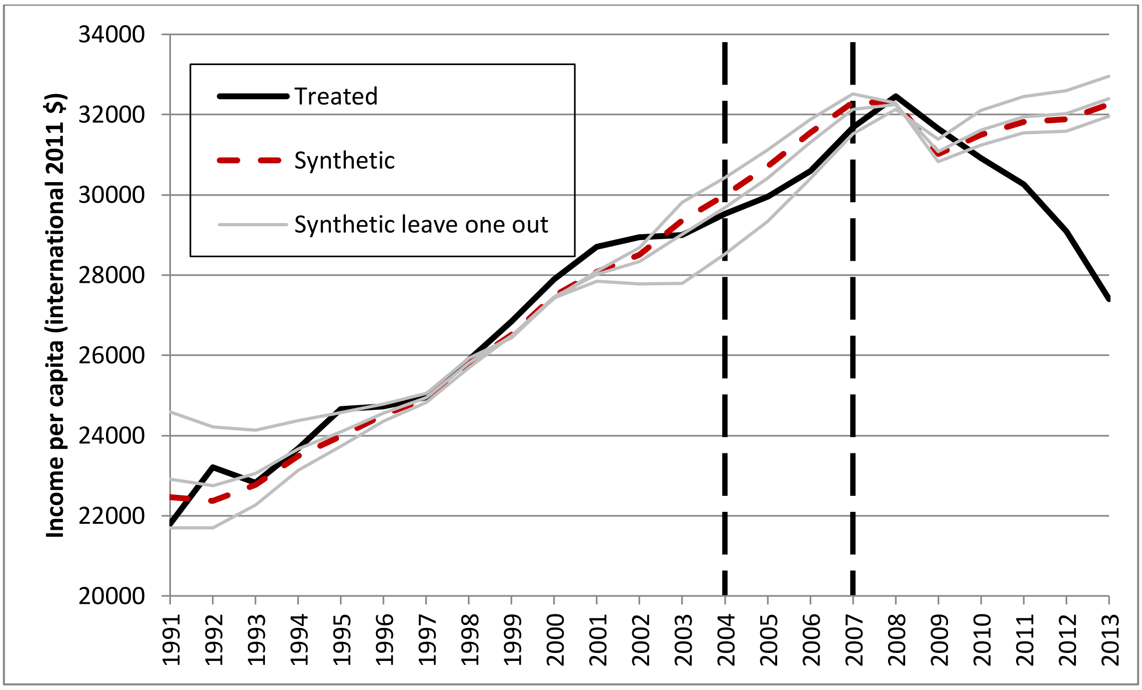
Note: The thin lines show the match when one of the countries with positive weights is excluded.

Figure 15: Leave-one-out weight robustness check, Slovenia, Growth



Note: The thin lines show the match when one of the countries with positive weights is excluded.

Figure 16: Leave-one-out weight robustness check, Cyprus, Income



Note: The thin lines show the match when one of the countries with positive weights is excluded.

Table 22: Ratio of post-intervention to pre-intervention RMSPE for different intervention dates

		Intervention year	
	Outcome variable	2004	Euro adoption year
Slovakia	income	3.20	3.06
Slovakia	growth	0.89	0.72
Slovenia	income	1.41	1.63
Slovenia	growth	3.14	3.79
Estonia (only Baltics)	growth	1.05	0.94
Malta	income	2.80	2.26
Cyprus	income	4.42	4.51
Cyprus	growth	1.22	1.55

9 Appendix B (Data quality)

Table 23: Data availability

	GDP_pc_WB	GDP_pc_IMF	GDP_growth	School_enrol	Industry_va	Inflation	Trade	Gov_exp	Age_dep	Infant_mortality	Investment	Current_account_balance
Albania	1990-2013	1990-2013	1990-2013	1990-2008	1990-2013	1990-2013	1990-2013	1990-2013	1990-2013	1990-2013	1990-2013	1990-2013
Croatia	1995-2013	1992-2013	1993-2013	1993-2003 2005-2012	1995-2013	1993-2013	1995-2013	1995-2013	1990-2013	1990-2013	1992-2013	1992-2013
Cyprus	1990-2013	1990-2013	1990-2013	1990-1997 1999-2012	1990-2008	1990-2013	1990-2010	1990-2010	1990-2013	1990-2013	1990-2013	1990-2013
Czech Republic	1990-2013	1995-2013	1996-2013	1990-2013	1993-2013	1994-2013	1990-2013	1990-2013	1990-2013	1990-2013	1995-2013	1995-2013
Estonia	1995-2013	1993-2013	1994-2013	1990-1996 1998-2012	1995-2013	1993-2013	1995-2013	1995-2013	1990-2013	1990-2013	1993-2013	1993-2013
Hungary	1991-2013	1990-2013	1990-2013	1990-1992 1994-2013	1995-2013	1990-2013	1991-2013	1991-2013	1990-2013	1990-2013	1990-2013	1990-2013
Iceland	1990-2013	1990-2013	1990-2013	1990-1996 1998-2011	1997-2012	1990-2013	1990-2013	1990-2013	1990-2013	1990-2013	1990-2013	1990-2013
Latvia	1990-2013	1992-2013	1993-2013	1990-2012	1990-2013	1992-2013	1990-2013	1990-2013	1990-2013	1990-2013	1992-2013	1992-2013
Lithuania	1990-2013	1999-2013	1996-2013	1990-2012	1990-2013	1993-2013	1990-2013	1990-2013	1990-2013	1990-2013	1995-2013	1995-2013
Macedonia	1990-2013	1992-2013	1993-2013	1993-2005 2007-2010 2012	1990-2013	1993-2013	1990-2013	1990-2013	1990-2013	1990-2013		1992-2013
Malta	1990-2013	2000-2013	1990-2013	2001-2008 2010-2012	1990-2010	1990-2013	1990-2011	1990-2011	1990-2013	1990-2013	1990-2013	1990-2013
Norway	1990-2013	1990-2013	1990-2013	1990-2012	1995-2013	1990-2013	1990-2013	1990-2013	1990-2013	1990-2013	1990-2013	1990-2013
Poland	1990-2013	1990-2013	1990-2013	1990-2012	1990-2013	1990-2013	1990-2013	1990-2013	1990-2013	1990-2013	1990-2013	1990-2013
Romania	1990-2013	1990-2013	1990-2013	1990-2012	1990-2013	1990-2013	1990-2013	1990-2013	1990-2013	1990-2013	1990-2013	1990-2013
Serbia	1995-2013	2000-2013	1999-2013	1999-2012	1995-2012	1995-2013	1995-2013	1995-2012	1990-2013	1990-2013	1998-2013	2000-2013
Slovakia	1992-2013	1993-2013	1994-2013	1993-2012	1995-2013	1994-2013	1990-2013	1990-2013	1990-2013	1990-2013	1993-2013	1993-2013
Slovenia	1995-2013	1992-2013	1993-2013	1993-1999 2004-2012	1995-2013	1993-2013	1995-2013	1995-2013	1990-2013	1990-2013	1992-2013	1992-2013
Sweden	1990-2013	1990-2013	1990-2013	1990-2012	1990-2013	1990-2013	1990-2013	1990-2013	1990-2013	1990-2013	1990-2013	1990-2013
Switzerland	1990-2013	1990-2013	1990-2013	1990-1996 1998-2012	1990-2013	1990-2013	1990-2013	1990-2013	1990-2013	1990-2013	1990-2013	1990-2013
Turkey	1990-2013	1990-2013	1990-2013	1990-1995 1997 1999-2012	1990-2013	1990-2013	1990-2013	1990-2013	1990-2013	1990-2013	1990-2013	1990-2013
United Kingdom	1990-2013	1990-2013	1990-2013	1990-2012	1990-2013	1990-2013	1990-2013	1990-2013	1990-2013	1990-2013	1990-2013	1990-2013

Note: Purple(dark) highlighting indicates IMF source, Green(bright) highlighting indicates WB source.

Table 24: Missing values by predictor

Predictor	Count	Missing	Missing %
School_enrol	445	59	11.7%
Industry_va	443	61	12.1%
Inflation	474	30	6.0%
Trade	474	30	6.0%
Gov_exp	473	31	6.2%
Age_dep	504	0	0.0%
Infant_mortality	504	0	0.0%
Investment	445	59	11.7%
Current_account_balance	465	39	7.7%
total	4227	309	6.8%

Table 25: Left – predictor missing values by Country, Right – predictor missing values by year

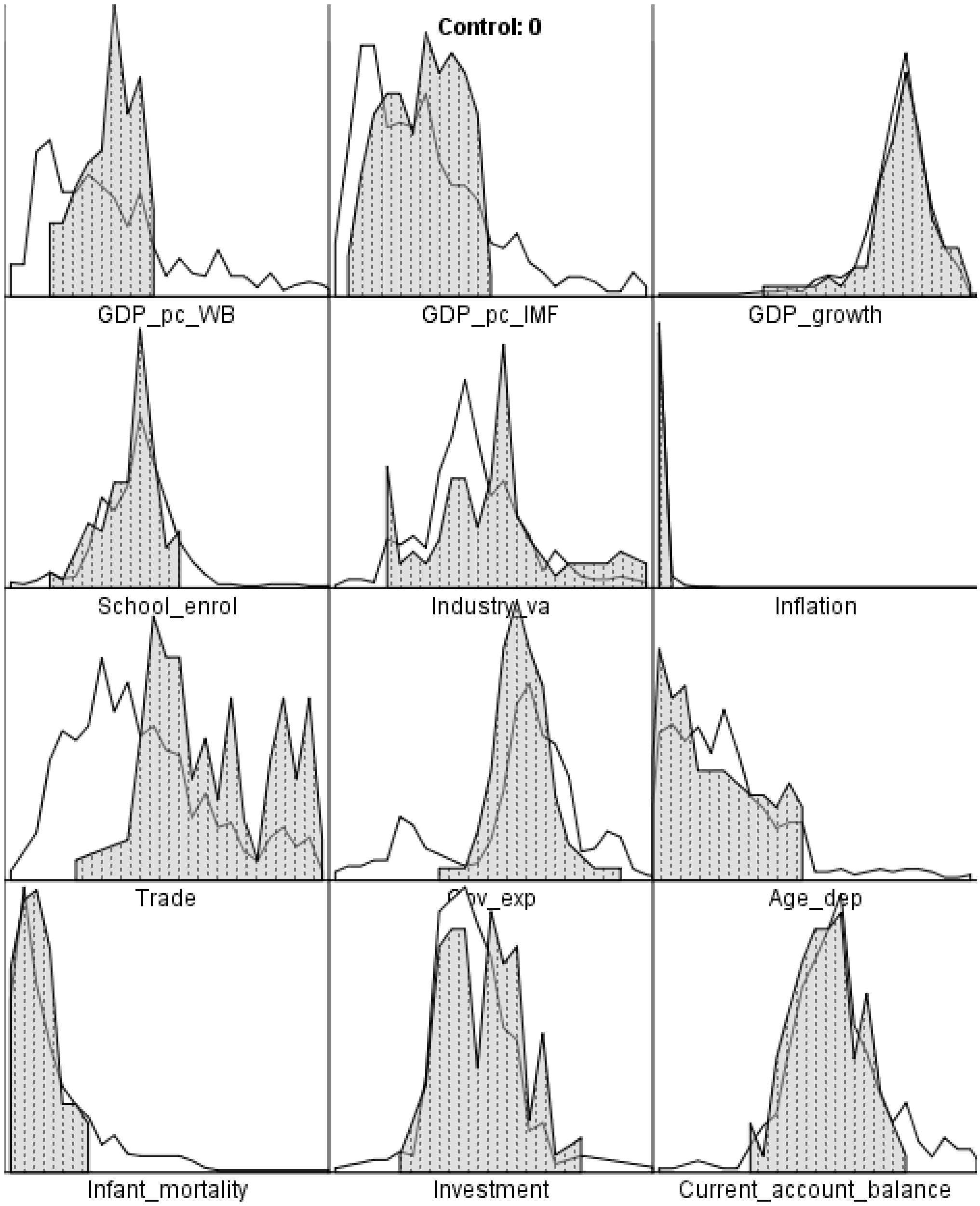
Country	Count	Missing	Missing %
Albania	211	5	2.3%
Croatia	189	27	12.5%
Cyprus	203	13	6.0%
Czech Republic	198	18	8.3%
Estonia	190	26	12.0%
Hungary	207	9	4.2%
Iceland	205	11	5.1%
Latvia	202	14	6.5%
Lithuania	195	21	9.7%
Macedonia, FYR	181	35	16.2%
Malta	197	19	8.8%
Norway	215	1	0.5%
Poland	210	6	2.8%
Romania	215	1	0.5%
Serbia	166	50	23.1%
Slovak Republic	197	19	8.8%
Slovenia	189	27	12.5%
Sweden	215	1	0.5%
Switzerland	214	2	0.9%
Turkey	213	3	1.4%
United Kingdom	215	1	0.5%
total	4227	309	6.8%

Year	Count	Missing	Missing %
1990	137	52	24.1%
1991	139	50	23.1%
1992	147	42	19.4%
1993	159	30	13.9%
1994	162	27	12.5%
1995	184	5	2.3%
1996	183	6	2.8%
1997	182	7	3.2%
1998	184	5	2.3%
1999	187	2	0.9%
2000	187	2	0.9%
2001	187	2	0.9%
2002	187	2	0.9%
2003	187	2	0.9%
2004	187	2	0.9%
2005	188	1	0.5%
2006	187	2	0.9%
2007	188	1	0.5%
2008	188	1	0.5%
2009	185	4	1.9%
2010	186	3	1.4%
2011	180	9	4.2%
2012	174	15	6.9%
2013	152	37	17.1%
total	4227	309	6.8%

Table 26: Outcome variable missing values

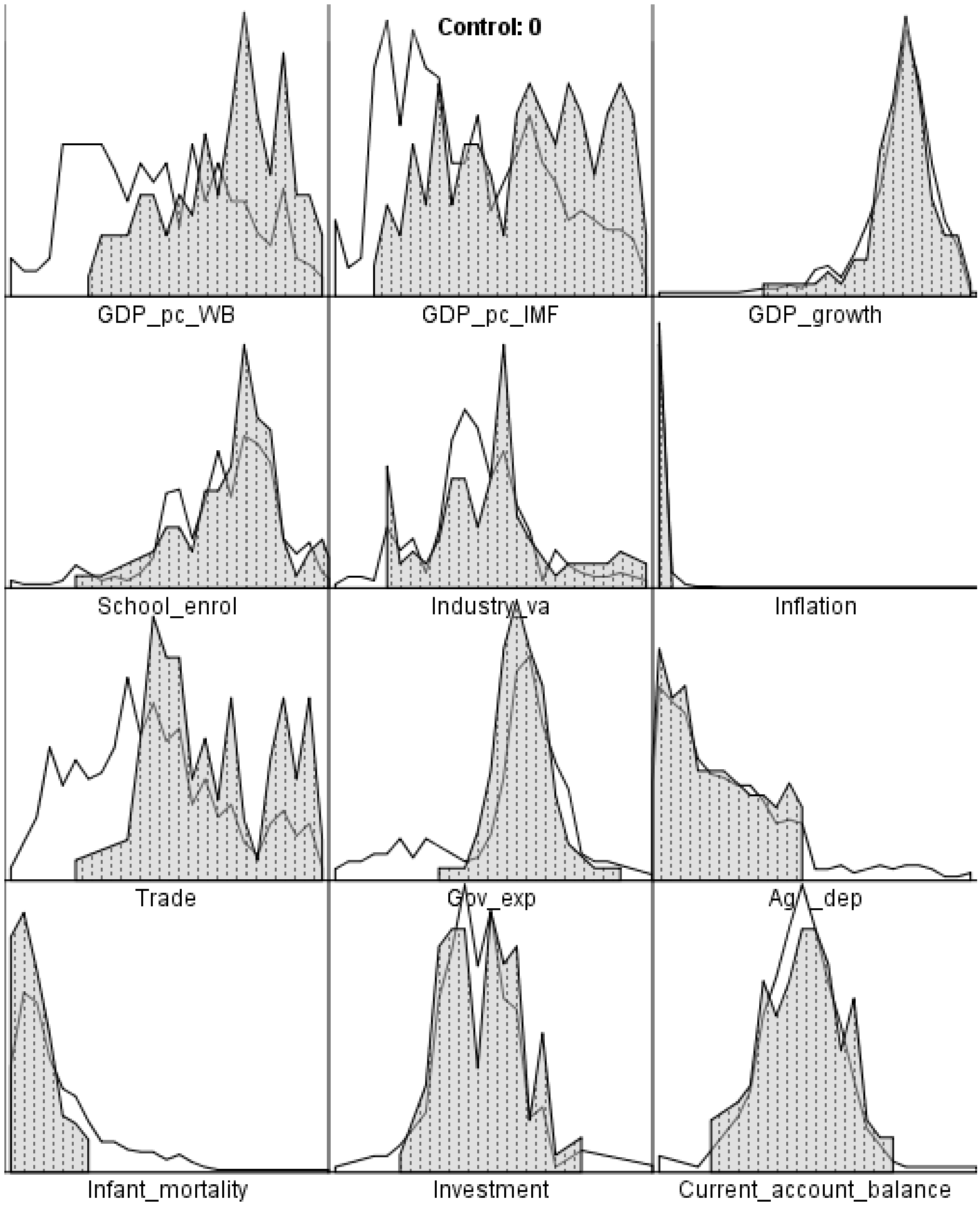
Predictor	Count	Missing	Missing %
GDP_pc_WB	481	23	4.6%
GDP_pc_IMF	456	48	9.5%
GDP_growth	452	52	10.3%

Figure 17: Distributions of treated units relative to Full sample



Note: Histograms show the distribution of full sample (white line), overlaid with the distribution of treated sample (grey area). If the whole width of grey area is within the plot, it can be fitted. The more similar the shape of the two areas, the more likely is the variable to improve fit.

Figure 18: Distributions of treated units relative to East sample



Note: Histograms show the distribution of East European sample (white line), overlaid with the distribution of treated sample (grey area). If the whole width of grey area is within the plot, it can be fitted. The more similar the shape of the two areas, the more likely is the variable to improve fit.

Table 27: Variable averages and boundaries, Full sample

	GDP_pc_WB	GDP_pc_IMF	GDP_growth	School_enrol	Industry_va	Inflation	Trade	Gov_exp	Age_dep	Infant_mortality	Investment	Current account balance
Albania	6208	5480	2.9	71.8	20.9	20.1	66.5	11.8	44.7	22.6	25.4	-7.0
Croatia	17890	14828	2.1	89.5	28.9	79.8	78.4	20.3	25.2	6.9	22.4	-3.7
Czech Republic	22886	20243	2.4	92.3	37.8	4.3	103.2	20.1	24.1	6.3	27.7	-3.5
Hungary	19191	16113	0.9	94.7	31.0	12.5	119.1	22.3	24.6	9.5	22.7	-4.5
Iceland	34756	29447	2.4	106.9	26.3	5.1	76.2	22.5	34.9	3.1	20.1	-6.8
Latvia	14236	13035	3.4	95.1	27.5	23.1	101.7	18.8	26.0	13.6	25.0	-4.5
Lithuania	15734	17065	4.6	97.5	33.0	28.6	111.2	19.4	28.0	9.7	21.6	-6.5
Macedonia, FYR	9302	8457	1.7	80.0	31.3	25.1	99.7	19.5	31.5	16.1		-5.3
Norway	56759	47942	2.5	113.4	37.8	2.2	71.4	21.2	29.7	3.9	22.2	9.7
Poland	15489	13212	3.3	96.7	33.4	37.3	63.7	19.4	28.0	8.7	20.9	-3.4
Romania	12892	10707	1.2	84.5	39.8	58.6	68.0	9.5	26.5	21.1	24.8	-5.8
Serbia	9983	9701	2.3	90.3	30.8	28.0	63.6	20.2	29.5	11.9	18.3	-8.9
Sweden	37248	29910	2.1	118.5	29.4	2.2	76.2	25.5	27.6	3.5	18.2	4.2
Switzerland	49185	39790	1.5	96.5	27.8	1.4	97.0	11.1	24.5	4.7	22.8	9.1
Turkey	13928	11831	4.2	74.8	30.1	43.1	46.0	12.6	48.0	32.9	20.8	-2.9
United Kingdom	32782	26482	2.2	99.2	25.5	2.7	54.1	19.3	28.3	5.5	16.9	-1.9
min	6 208	5 480	0.9	71.8	20.9	1.4	46.0	9.5	24.1	3.1	16.9	-8.9
max	56 759	47 942	4.6	118.5	39.8	79.8	119.1	25.5	48.0	32.9	27.7	9.7

Table 28: Variable averages, Treated countries

	GDP_pc_WB	GDP_pc_IMF	GDP_growth	School_enrol	Industry_va	Inflation	Trade	Gov_exp	Age_dep	Infant_mortality	Investment	Current account balance
Cyprus	27450	23804	3.1	91.2	21.3	3.1	100.8	17.5	31.8	5.6	20.5	-5.0
Estonia	18969	15997	4.3	101.2	29.2	12.9	131.4	19.2	26.8	8.6	30.2	-6.5
Malta	23942	25038	1.8	85.3	44.7	2.7	169.9	19.3	29.0	7.0	19.8	-5.3
Slovak Republic	18656	16487	4.3	90.1	35.8	5.7	131.4	19.9	28.1	10.0	26.3	-4.7
Slovenia	25181	20939	2.8	93.7	34.0	7.4	114.8	18.8	23.2	4.7	25.1	-0.3

Note: Red(dark) shading indicates values higher than maximum in control sample. Green(bright) shading indicates values lower than minimum in control sample.

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Annex

This part arrives at the formal relationship between estimator bias and length of observation period.

Suppose we have J units, the first unit ($j=1$) being the treated one, i.e. the one which will experience intervention. The remaining $J-1$ units are the control group, unaffected by the intervention. Assume we have a total of T periods, split into T_0 pre-intervention periods and $T- T_0$ post-intervention periods. Now for each unit $j=1,\dots,J$ and time $t=1,..,T$, we observe outcome variable Y_{jt}. For each unit j we also have observed vector of unit characteristics ($X_{1j},\dots, X_{kj}$). We define Y_{it}^N as the outcome variable in case of no intervention. Then, for the affected unit $j=1$, with post-intervention periods $t \in [T_0 + 1, T]$, we are interested in the treatment effect in periods after intervention:

$$\alpha_{1t} = Y_{1t} - Y_{1t}^N \tag{1}$$

Now we need to get Y_{1t}^N. Abadie et al. (2010) use following factor model:

$$Y_{it}^N = \delta_t + \theta_t Z_i + \lambda_t \mu_i + \varepsilon_{it}, \tag{2}$$

where δ_t is an unknown common factor with constant factor loadings across units (time effect), Z_i is a vector of observed pre-intervention covariates, θ_t is a vector of unknown parameters, λ_t is a vector of observed common factors, μ_i is a vector of permanent unknown factor loadings and ε_{it} are observed transitory shocks at the unit level with zero mean and independent. Suppose a vector of weights $w = (w_2, \dots w_J)$, where $w_j \in [0,1]$ and $\sum_{j=2}^{J} w_j = 1$. The value of outcome variable indexed by w is:

$$\sum_{j=2}^{J} w_j Y_{jt} = \delta_t + \theta_t \sum_{j=2}^{J} w_j Z_j + \lambda_t \sum_{j=2}^{J} w_j \mu_j + \sum_{j=2}^{J} w_j \varepsilon_{jt}$$

Suppose there are weights that satisfy following conditions:

$$\sum_{j=2}^{J} w_j^* Y_{j1} = Y_{11}, \quad \sum_{j=2}^{J} w_j^* Y_{j2} = Y_{12}, \quad \cdots \quad \sum_{j=2}^{J} w_j^* Y_{iT_0} = Y_{1T_0},$$
$$\text{and} \qquad \sum_{j=2}^{J} w_j^* Z_j = Z_1. \tag{3}$$

Then the estimator of treatment effect α_{1t} is:

$$\hat{\alpha}_{1t} = Y_{1t} - \sum_{j=2}^{J} w_j^* Y_{jt} \tag{4}$$

Abadie et al. (2010) in their Appendix B prove that bias of this estimator is bounded by a term which decreases with length of observation period:

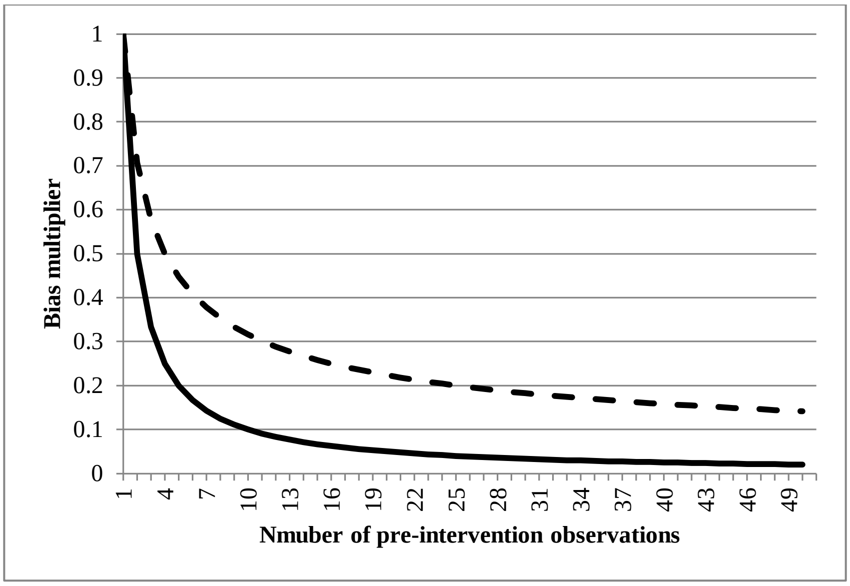
$$|\mathrm{E}(\hat{\alpha}_{1t} - a_{1t})| = \beta\, J^{\frac{1}{p}}\, max\left\{\left(\frac{m_p}{T_0^{p-1}}\right)^{\frac{1}{p}}, \frac{\bar{\sigma}}{\sqrt{T_0}}\right\} \tag{5}$$

Where m is maximum over average error per unit ε_j , $\bar{\sigma}$ the variance of those errors, β stands for a group of coefficients (see the original paper for detailed description) and p is a some even constant. What we can see from the right hand side part of equation (5) is that bias will decrease with increasing number of observations at a decreasing rate. Table and Figure bellow approximate the decrease in bias with increasing length observation period. In this simulated exercise, the minimal threshold for effective decrease in bias may be around 20 observations.

Table: Approximate bias multiplier due to number of observations

T	Decrease in bias (1/T)	Decrease in bias ($1/T^{1/2}$)
1	1.000	1.000
2	0.500	0.707
3	0.333	0.577
4	0.250	0.500
5	0.200	0.447
6	0.167	0.408
7	0.143	0.378
8	0.125	0.354
9	0.111	0.333
10	0.100	0.316
11	0.091	0.302
12	0.083	0.289
13	0.077	0.277
14	0.071	0.267
15	0.067	0.258
16	0.063	0.250
17	0.059	0.243
18	0.056	0.236
19	0.053	0.229
20	0.050	0.224
21	0.048	0.218
22	0.045	0.213
23	0.043	0.209
24	0.042	0.204
25	0.040	0.200
26	0.038	0.196
27	0.037	0.192
28	0.036	0.189
29	0.034	0.186
30	0.033	0.183
31	0.032	0.180
32	0.031	0.177
33	0.030	0.174
34	0.029	0.171
35	0.029	0.169
36	0.028	0.167
37	0.027	0.164
38	0.026	0.162
39	0.026	0.160
40	0.025	0.158
41	0.024	0.156
42	0.024	0.154
43	0.023	0.152
44	0.023	0.151
45	0.022	0.149
46	0.022	0.147
47	0.021	0.146
48	0.021	0.144
49	0.020	0.143
50	0.020	0.141

Figure: Approximate bias multiplier due to number of observations



Note: Solid line corresponds to second column, dashed line to third column of the table.